Appendix D
SEC Roadmap Mission Fact Sheets

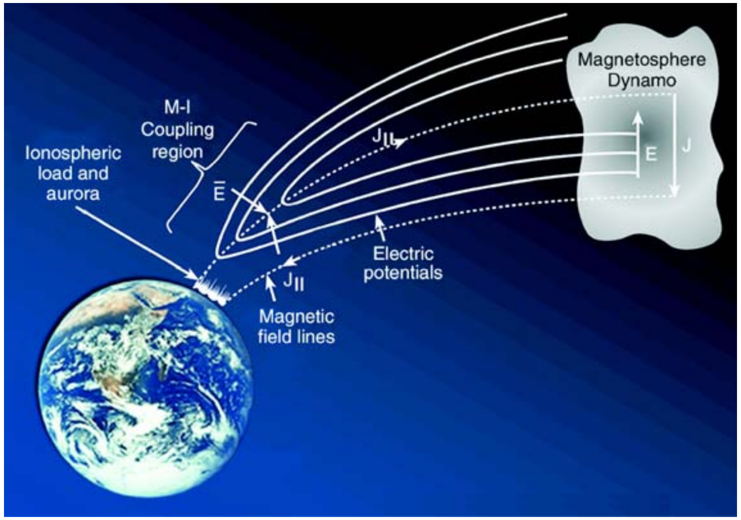
The following pages contain the SEC Mission Fact Sheets in alphabetical order. These missions include the STP and LWS missions in formulation and development, supporting international missions, and the SEC Roadmap Missions for the intermediate-term and the long-term.

Appendix D
SEC Near-, Intermediate-, and Long-Term Missions

Alphabetical Listing:

- Auroral Multi-Scale (AMS)
- Bepi-Colombo
- Dayside Boundary Layer Constellation (DBC)
- Geospace Electrodynamics Connections (GEC)
- Geospace Storm Probes
  - Ionosphere Thermosphere Storm Probes
  - Radiation Belt Storm Probes
- Geospace System Response Imager (GSRI)
- Heliospheric Imager and Galactic Observer (HIGO)
- Inner Heliosphere Sentinels (IHS)
- Inner Magnetospheric Constellation (IMC)
- Interstellar Probe
- Io Electrodynamics
- Ionosphere Thermosphere Mesosphere Waves Coupler
- Jupiter Polar Orbiter (JPO)
- L1-Diamond
- Magnetic TRAnsition region Probe (MTRAP)
- Magnetospheric Constellation (MC)
- Magnetosphere-Ionosphere Observatory (MIO)
- Magnetospheric Multiscale (MMS)
- Mars Aeronomy Probe
- Neptune Orbiter
- Particle Acceleration Solar Orbiter (PASO)
- Reconnection and Microscale (RAM)
- Solar-B
- Solar Connection Observatory for Planetary Environments (SCOPE)
- Solar Dynamics Observatory (SDO)
- Solar Imaging Radio Array (SIRA)
- Solar Orbiter
- Solar Polar Imager
- Solar Probe
- Solar-TERrestrial RElations Observatory (STEREO)
- Stellar Imager
- Sun-Earth Energy Connector (SEEC)
- Sun-Heliosphere-Earth Constellation
- Telemachus
- Tropical ITM Coupler
- Venus Aeronomy Probe

Auroral Multi-Scale



Minimum Technology Design was baselined

- No "enabling" technology required
- New enhancing technology should reduce spacecraft cost by 10%

Science Objectives

To understand the electrodynamic connection between Earth's ionosphere and magnetosphere

- What structures accomplish the connection?
- What is the electrical impedance and how is it established?
- What is the role of ionospheric feedback?
- How does magnetospheric dynamics affect the coupling?

Mission Description

- Four spacecraft flying in formation through the mid-altitude M-I coupling region, supported by on-board auroral UV imaging
- 600 X 7,000 km orbits
- Small orbital maneuvers to achieve near tetrahedral configuration at desired point in orbit

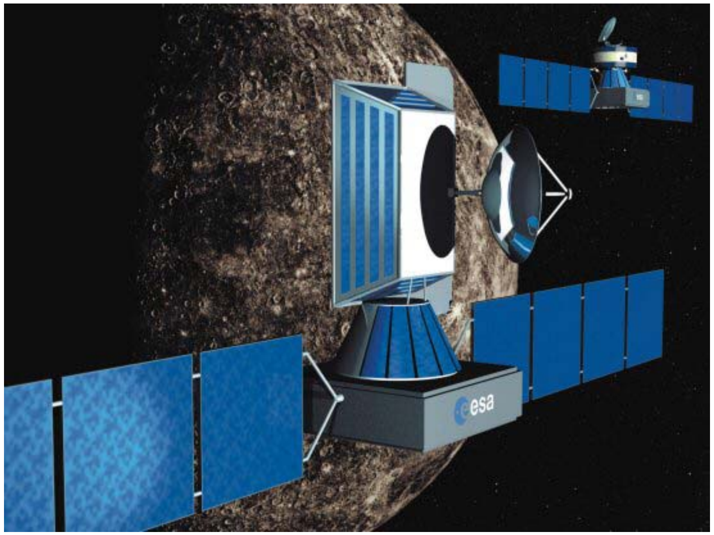
Measurement Strategy

- Measure j: B & precision attitude (0.02° maximum error)
- Measure ϕ: DC E-field, particle distribution, || B necessary
- Distinguish waves, static structures: ~10 µsec timing
- Identify kinetic processes via established signatures

UV Auroral imaging

- Establish context: motions, forms, and conductivity structures
- FOV focused along magnetic foot-point
- Daytime and nighttime imaging needed

Bepi-Colombo



Technology

- Solar Electric Propulsion will be demonstrated on ESA’s technology mission, SMART-1 (2003)
- High Temperature (HT) MLI, HT coatings
- HT, high intensity GaAs solar cells
- HT, 2-axis large amplitude antenna articulation mechanism
- HT X/Ka high gain antenna reflector and feeds
- Miniaturized integrated electronics for HT environments
- Mercury Horizon Sensor, HT Sun Sensors
- Lander

Science Objectives

- Measure the composition, state and distribution of mass within Mercury’s interior.
- Map Mercury’s intrinsic magnetic field and determine the nature of its interaction with the solar wind.
- Measure the composition, density, and dynamic variations in the charged particles that populate Mercury’s magnetosphere.
- Image the entire surface of mercury at a resolution <100 m and determine its composition.
- Determine if water ice exists in deep craters in Mercury’s polar regions.
- Measure the composition and density of Mercury’s tenuous exosphere.

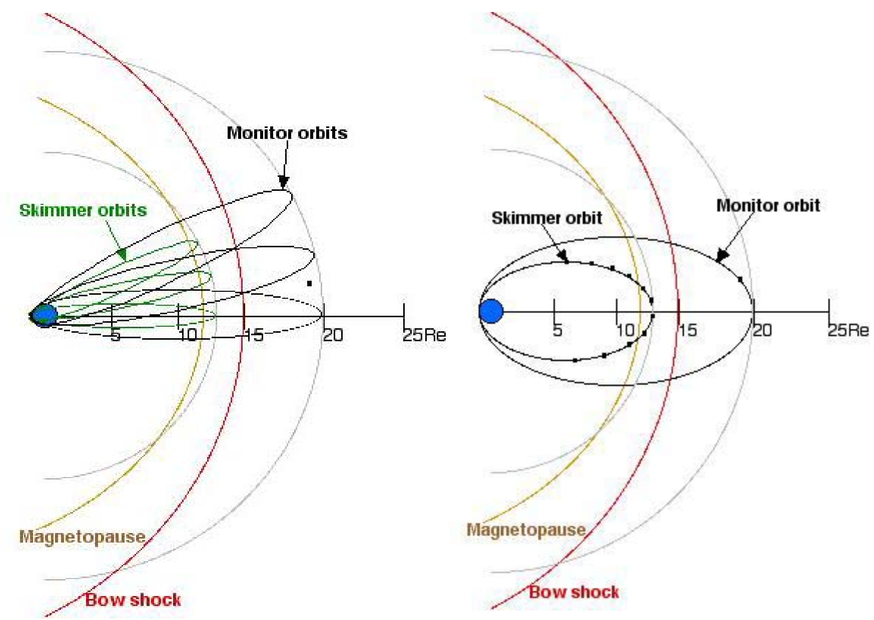
Mission Description

- 2-3 ESA/ISAS spacecraft using SEP and gravity assist (Moon, Venus, Mercury) to orbit Mercury
  - (MPO) Mercury Polar Orbiter (ESA) (3AS)
  - (MMO) Magnetospheric Orbiter (ISAS) (Spinner)
  - (MSE) Mercury Surface Element (ESA (if approved)
- Option 1: 2 spacecraft on 2 separate Soyuz-Fregat Launchers as much as 1 year apart
- Option 2: 3 spacecraft on 1-Ariane V
- Launch 2009-1010

Measurement Strategy

- Planetary orbiter (MPO):
  - 3-axis stabilized
  - Visible/near IR camera, photon spectrometers (IR, UV, X-ray, gamma-ray), neutron spectrometer, accelerometer, K-band transponder
- Magnetospheric orbiter (MMO):
  - Spin-stabilized
  - Magnetometer, ion spectrometer, ion/electron analyser, cold plasma detector, energetic particle detector
- Surface element (MSE):
  - Physical properties and geochemistry package, camera, seismometer
- MPO remote sensing

Dayside Boundary Constellation



Equatorial View

Polar View

Minimum New Technology

- No “enabling” technology required
- Low level long duration thrust needed for orbit precession – small solar sail potential

Science Objectives

- Measure highly asymmetric and dynamic bow shock and magnetopause structures which regulate the solar wind’s impact on the magnetosphere.
- Establish the casual relationship(s) between these boundary phenomena and corresponding solar wind, foreshock, and magnetosheath drivers.

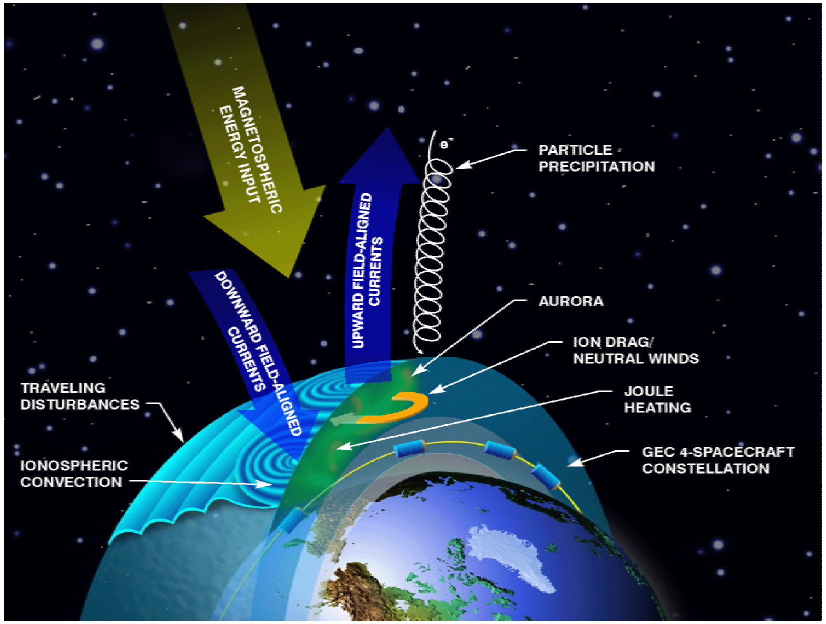
Mission Concept

- Orbits: 3 orbit planes near equator with 30 deg separation
  - Active precession to keep apogee on earth sun line
  - 11 “skimmers”per plane with 11 to 12 Re apogee
  - 1”monitor” per plane with ~ 20 Re apogee
- “Skimmer” separations range from 1 to 5 Re near apogees in phase with those of “monitors”

Measurement Strategy

- **Minimum measurement compliment to**
  - Identify boundary layer, magnetopause and shock crossings
  - Determine timing over ~Re separations: $\Delta t \sim 60$ seconds between SC
  - Measure solar wind & IMF (monitors)
- **Vector magnetic field**
  - ~0.5 nT accuracy, ~0.1 nT resolution
  - 0.1 sec resolution (required to despin)
- **Plasma**
  - Ions: density, flow, temperature. ~5 sec resolution
  - Electrons: 50 eV to 1 keV. ~5 sec resolution.

Geospace Electrodynamic Connections (GEC)



Science Objectives

- Understand the response of the Ionosphere-Thermosphere system to Magnetosphere forcing
- Resolve the dynamic coupling of the Ionosphere-Thermosphere system to the Magnetosphere

Mission Description

- A constellation of four spacecraft flying in formation (Pearls-On-A-String) each carrying identical sets of nine instruments.
- 185 X 2,000 km; 83 degree inclination parking orbit
- Orbital maneuvers, at select times, to lower perigee to an altitude of ~ 130 km, lasting up to one week

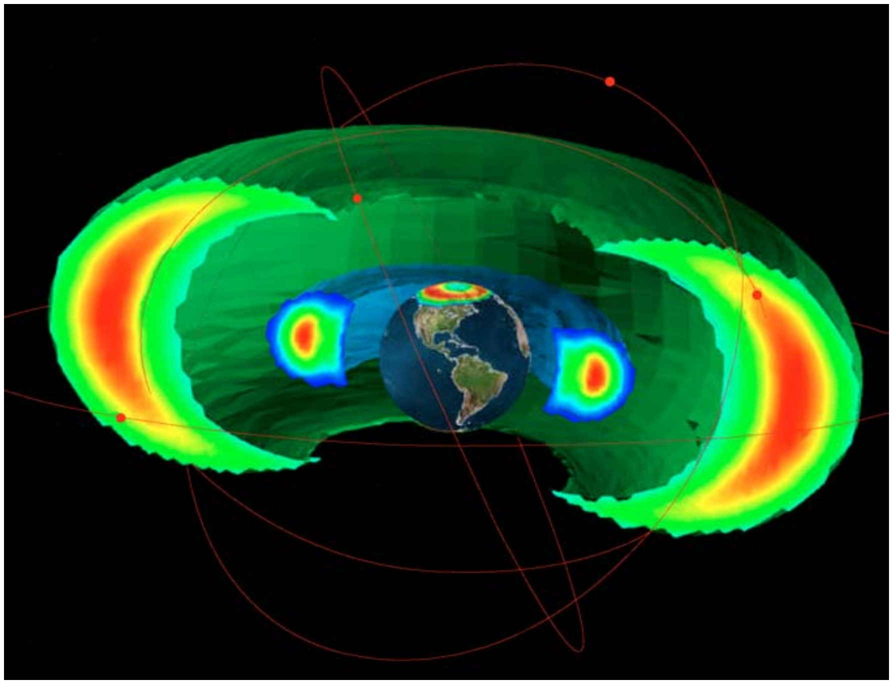
Measurement Strategy

- Measure in-situ all relevant plasma-neutral coupling parameters
- Spacecraft cross important high latitude magnetosphere-ionosphere coupling regions
- Unequal, variable spacecraft spacings to resolve different scales
- Low dips to altitude where atmosphere begins to dominate the plasma dynamics.

Key Mission Enhancing Technologies

- Aerodynamic Structures & Materials
- Low Magnetic & Electric Field Emissions
- Body Mounted Solar Arrays (ESC) with Lightweight/Rigid Booms
- Precise formation flying

Geospace Storm Probes



Minimum Technology Design was Baselined

- Enabling technology development in high-radiation avionics pending
- New enhancing technology should reduce spacecraft cost for multiple-spacecraft investigations

Science Objectives

- Characterize and understand acceleration, global distribution, and variability of the radiation belt electrons and ions that produce the harsh environments for spacecraft and humans
- Characterize and understand mid-latitude ionospheric variability and irregularities that affect communications, navigation, and radar systems

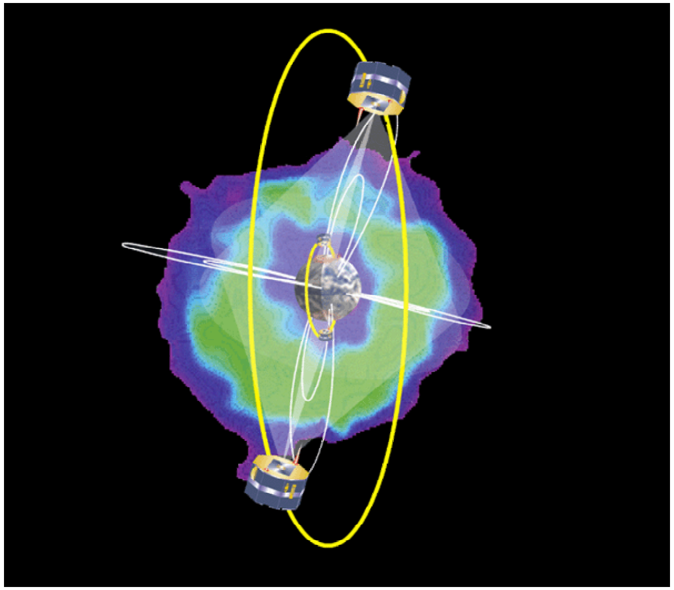
Mission Description

- Ionospheric-Thermospheric Storm Probes (ITSP)
  - Two spacecraft in nearly identical, 60°-inclination, circular orbits at a nominal altitude of 450 km
  - Both spacecraft identically instrumented to characterize the dynamic response of the I-T system to variable solar EUV flux and geomagnetic storms
- Radiation Belt Storm Probes (RBSP)
  - Two spacecraft in nearly identical, low-inclination (<18°, 12° goal), highly elliptical (500 km × 5.5 R_E) "chasing" orbits for magnetic shell coverage
  - First spacecraft fully instrumented for in situ measurements of radiation belt particles, fields, and background environment
  - Second spacecraft with subset of instruments for simultaneous multipoint measurements in radiation belts
- Global Mid-Latitude UV Imaging
  - UV imager on a non-LWS geosynchronous spacecraft

Measurement Strategy

- Ionospheric-Thermospheric Storm Probes (ITSP)
  - DC electric fields (ion drifts), neutral wind vector, plasma density and fluctuations, plasma density altitude profile, neutral density and mass composition, neutral temperature, scintillations
- Radiation Belt Storm Probes (RBSP)
  - Radiation belt electrons, vector magnetic field, ring current particles, AC magnetic fields, DC/AC electric fields
- Global Mid-Latitude UV Imaging
  - Ultraviolet measurements of O/N_2 ratio and electron density
- Concurrent observations by RBSP, ITSP, the Global Mid-Latitude UV Imaging, and a Solar Dynamics Observatory EUV imager

Geospace System Response Imager (GSRI)



Measurement Strategy

- Two high altitude spacecraft with global ENA and EUV imaging magnetosphere, and high high resolution global spectroscopic FUV and x-ray imaging of the I-T system – all data available real-time
- Two low altitude spacecraft with Fabrey-Perot interferometers and in-situ field and particle measurements
- Ground radar measurements coordinated with space-based sensors

Minimum Technology Design was baselined:

- No "enabling" technology required
- New enhancing technology should reduce spacecraft cost by 10%

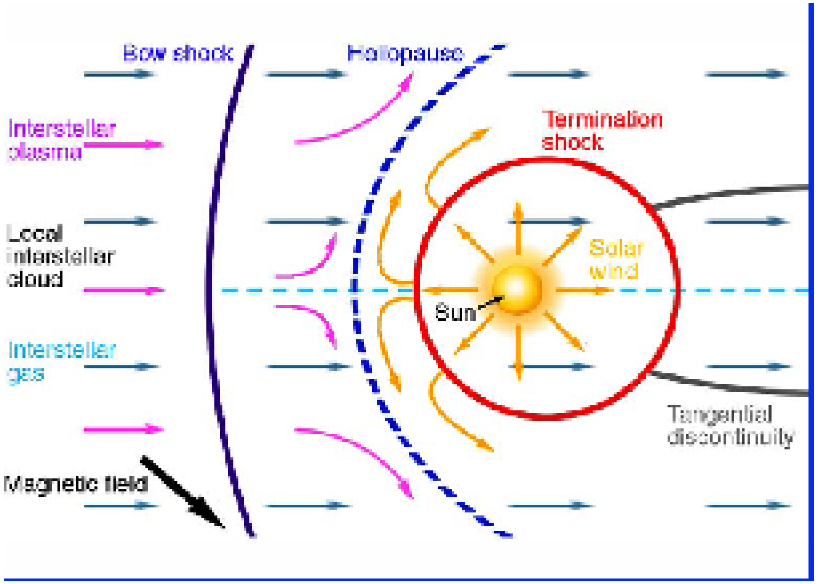
Science Objectives

- Determine dynamic coupling between ionosphere and magnetosphere
- Determine how magnetospheric energy is dissipated in the Ionosphere-Thermosphere (I-T) system
- Determine the important feedback mechanisms from the I-T system to the magnetosphere
- Determine global magnetospheric dynamics
- Determine causes and consequences of magnetospheric storms and sub-storms

Mission Description

- Mission Design
  - 2 Low Altitude Spacecraft (LAS) in 500-km sun-synchronous (97.4-degree inclination)
  - 2 High Altitude Spacecraft (HAS) in 8Re circular orbit also at 97.4-degree inclination
  - Ground-based radar network covers 30 to 90 deg north and south latitudes
  - 2 year life
- Payload
  - LAS F-P Interferometer plus in-situ ions and Mag field instruments nadir and RAM oriented
  - HAS 8 Imaging instruments nadir pointing with roll about nadir
  - 10 ground radar installations with 2 antennas each

Heliosphere Imager and Galactic Observer



Science Objectives

- Establish the 3-D Structure of the Interaction Region Between the Heliosphere and the Local Galactic Environment
- Determine the Nucleosynthetic Status of a Present-Day Sample of the Galaxy and Explore the Implications of this Knowledge for Big Bang Cosmology, Galactic Evolution, Stellar Nucleosynthesis, and the Birthplace of the Sun
- Characterize the Physical State of the Local Interstellar Cloud and the Nature of its Interaction with the Heliosphere
- Map the Location and Establish the Characteristics of the Extended Inner Source of Neutrals in the Heliosphere, and Set Limits on the Dust Density in the Heliosphere
- Search for molecules and the building blocks of life liberated by sublimation of small comets, asteroids and grains (detectable through measurement of pickup particles)

Mission Description

- Example Mission Design
  - Delta II 2925 Launch, 745 kg @ $C_3 = 26.4\ km^2/s^2$ (25.3 min)
  - ΔV-EGA (2-) Trajectory
    - 2.8 year cruise, 2 year orbital science operations
    - 1 x 4 AU Equatorial Final Orbit
- Flight System Concept
  - Spin-Stabilized Platform
  - Solar Array Design
  - Payload: 71 kg, 62 W, 1 kbps
  - 628 m/s ΔV
  - 900 arcsec (control), 360 arcsec (knowledge)

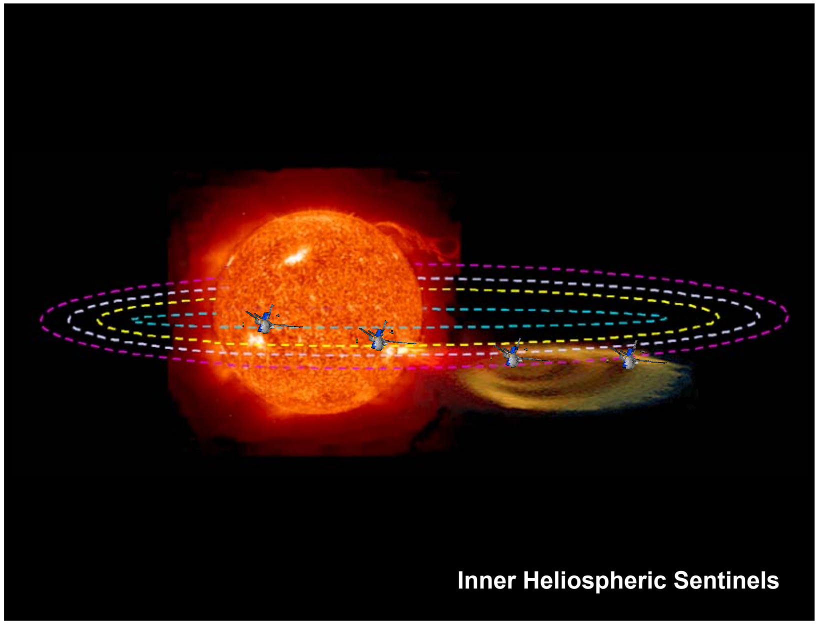
Measurement Strategy

- Image the Heliopause using Global Sky Maps of 83.4 O+
- Image the Termination Shock using Energetic Hydrogen Atoms and Radio Detection (2-5 kHz)
- Determine the isotopic and elemental composition of the neutral portion of the interstellar gas from measurements of pickup ions and of the main neutral species
- Determine the Flow Direction, Speed and Temperature of Interstellar Atoms
- Determine Composition and Radial Profiles of Extended Inner Source Pickup Ions
- Determine Time-dependent Interactions of Large-Scale Structures with Heliospheric Interfaces through Radio Detection (2-5 kHz)

Enabling Technology Development

- High resolution diffuse EUV Spectrometer
- Advancing anti-coincidence noise suppression technique
- Negative Ion Conversion Surface

Inner Heliospheric Sentinels



Technology Development

- High Temperature Solar Arrays
- Advanced Thermal Control
- Low Mass/Power High-Density Data Storage

Science Objectives

- Determine how the global character of the inner heliosphere changes with time
- Understand how geo-effective structures (CMEs, shocks, CIRs) propagate and evolve from Sun to 1 AU
- Discover what solar dynamic processes are responsible for the release of energetic particles and geo-effective events
- Constrain heliospheric models

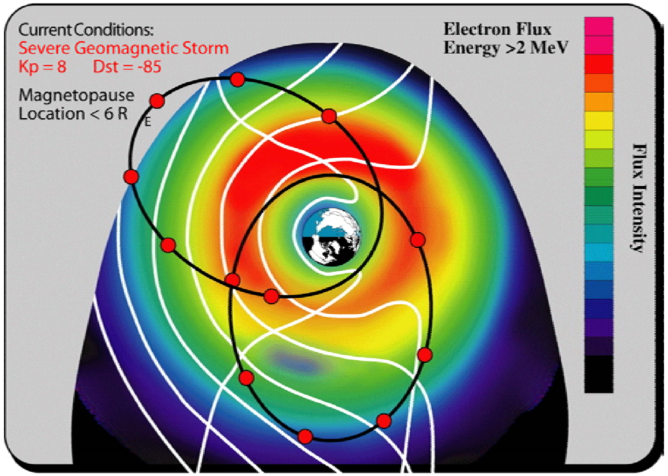
Mission Description

- Example Mission Design
  - Delta II or III Launch Vehicle
  - Trajectory:Ballistic w/ Venus Gravity Assist(s)
  - Elliptical Heliocentric Orbits
    - R_p = 0.4, 0.45, 0.72, 0.72 AU
    - R_a = 0.76, 0.79, 0.8, 0.95 AU
  - 0.5 – 1 yr cruise, 4.5 – 4 yr science ops
- Flight System Concept
  - Spin Stabilized (4 Dual-String S/C)
  - Solar Array Implementation
  - Telecom: X-band UP, Ka-band DOWN

Measurement Strategy

- Magnetic field, solar wind particle distribution, energetic particle and radio and plasma wave measurements
- Longitudinally distributed and concentrated solar observations

Inner Magnetospheric Constellation (IMC)



Minimum Technology Design was Baselined

- No "enabling" technology required
- New enhancing technology should reduce spacecraft cost by 10%

Science Objectives

- Create time-dependent maps of the inner magnetosphere (1.5-12 RE)
- Fully specify and understand the space environment where spacecraft and astronauts work.
- Discover the origin and dynamics of magnetospheric particle populations
- Derive the global, time-dependent magnetic and electric fields.
- Determine the development and evolution of magnetic storms.

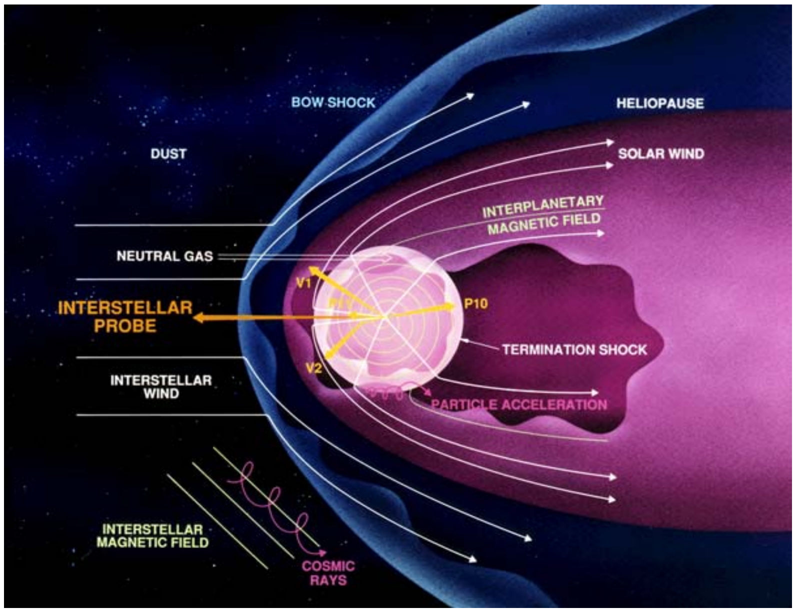
Mission Description

- 2 "petal" low inclination orbits that maintain uniform coverage independent of precession.
- 3 satellites per orbit, 6 total.
- Instruments: 3-axis Magnetometer, Electron Analyzer, Energetic Particles, 2-axis Electric Fields

Measurement Strategy

- The large-scale equatorial electric & magnetic fields are directly measured.
- An independent measurement of the fields - integrated along particle drift paths - is obtained from the energetic particle phase space density contours.
- Different energies have different drift paths and highly constrain the construction of global synoptic "weather maps" of the inner magnetospheric response to geomagnetic disturbances originating on the Sun..
- Direct measurement of the origin and dynamics of global particle structures such as the ring current, the relativistic electron radiation belts, the plasmasphere and detached/extruded plasmaspheric populations.

Interstellar Probe



Technology

- Solar Sail: < 1 g/m^2, 200 m radius
- DSN 70m Subnet w/ Ka-band Uplink
- Next Generation ARPS
- Next Generation System On A Chip
- Ka-band S/C Components and Phased Array
- Hot-Gas Propulsion
- Micro-S/C Technology
- Low Mass/Power Instrumentation

* Nuclear Electric Propulsion (NEP) may be a future implementation, developments within the Nuclear Systems Initiative will be closely followed and utilized to their fullest advantage

Science Objectives

- Explore the interstellar medium and determine directly the properties of the interstellar gas, the interstellar magnetic field, low-energy cosmic rays, and interstellar dust
- Determine the structure and dynamics of the heliosphere, as an example of the interaction of a star with its environment
- Study, in situ, the structure of the solar wind termination shock, and the acceleration of pickup ions and other species
- Investigate the origin and distribution of solar-system matter beyond the orbit of Neptune

Mission Description

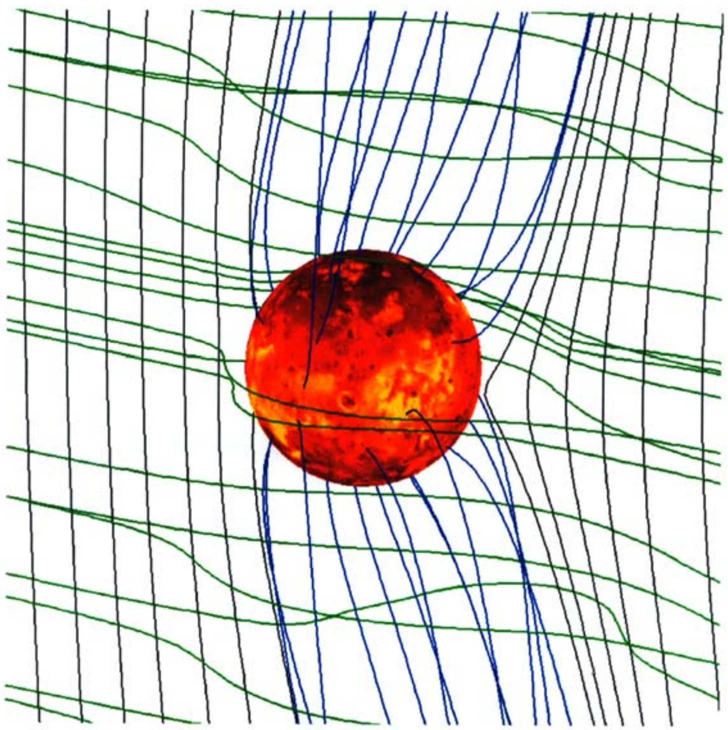
- Example Mission Design*
  - Delta II 7425 Launch (719 kg Cap., C_3 = 0 km^2/s^2)
  - Flight System Launch Mass: 564 kg
  - Solar Sail Trajectory Targeted for Nose of Heliosphere
    - 0.25 AU Solar Pass, 200 AU in 15 yrs.
- Flight System Concept
  - “Flying Antenna” Design Implementation (191 kg)
  - Sized for 30 year Operations
  - Payload: Fields & Particles + Imaging

Measurement Strategy

- Measure, in situ, the properties and composition of interstellar plasma and neutrals, low energy cosmic rays, and interstellar dust
- Determine the structure and dynamics of the heliosphere with in situ measurements and global imaging
- Map the infrared emission of the zodiacal dust cloud, measure in situ the distribution of interplanetary dust, and determine the radial distribution of small Kuiper Belt objects

Io Electrodynamics

Magnetic Field Lines and Flow Stream Lines Near Io



Science Objectives

- Investigate the Energy Conversion Processes in a Magnetized Plasma
- Understand Mass Transport in a Rapidly Rotating Magnetosphere
- Determine How Intense Parallel Electric Fields are Generated in a Magnetized Plasma
- Determine How Momentum is Transferred Through Field-Aligned Current Systems
- Determine the Role of Io on Radio Wave Generation at Jupiter

Mission Description

- Example Mission Design
  - Delta III Launch: Direct Trajectory
  - Elliptical Io-Resonant Equatorial Orbit
    - 5.9 R_j x 71 R_j , ~ 1 mo. Orbital Period
    - 2-Year Flight Time, 3-Year OPS
- Flight System Concept
  - Rad-Hard Spin-Stabilized Platform
  - Chem/Bi-Prop w/ ARPS Implementation
  - Payload:
    - Fields & Particles Instrumentation (Plasma, Energetic Particle, Magnetic & Electric Fields)
    - UV Imager

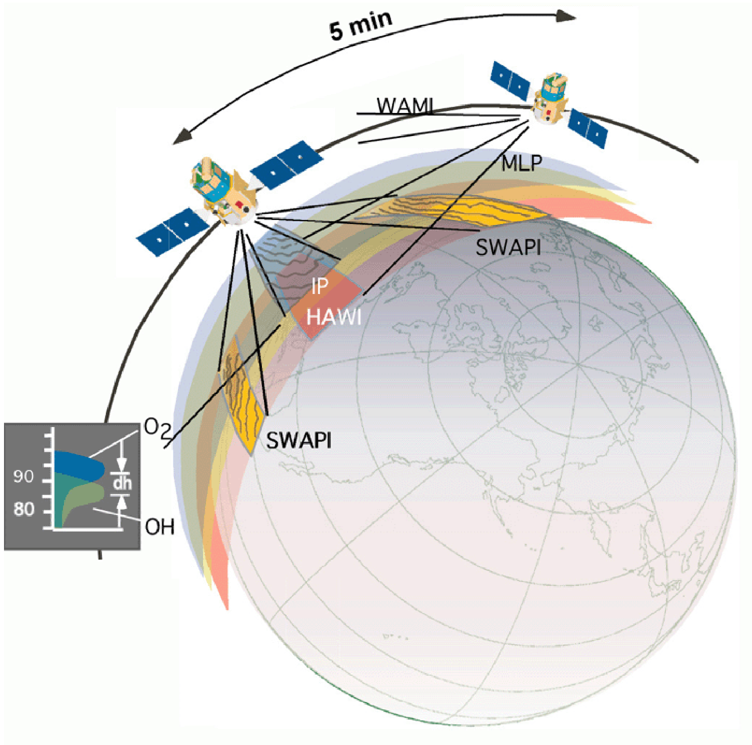
Enabling Technology Development

- Rad-Hard Electronics/ACS Sensors
- Advanced Radioisotope Power

Measurement Strategy

- Multiple Flybys of Io
- Different Science Emphasis for Each Encounter/Flyby
- High Resolution Flyby Data Stored in Mass Memory for Playback Over Post-Encounter Trajectory (Apojove)
- Image Jupiter aurora to track magnetic footprint of Io

Ionospheric-Thermospheric-Mesospheric Waves Coupler



Science Objectives

- Global measurements of small scale gravity waves in the Earth's MLTI region
- Determine the exchange rate of water vapor between the troposphere and thermosphere

Mission Description

- 2 satellites in 650 km circular orbits
  - 30°: 2 years lifetime beginning when both satellites are on orbit
  - 70°: 6 years lifetime for water vapor measurement (desired)
- Payload (nadir and ram pointing)
  - 5 remote sensing
  - 2 in situ instruments

Measurement Strategy

- Type
  - Optical remote sensing of airglow emissions, cloud height, wind fields, and water vapor
  - In situ measurement of electron and ion densities

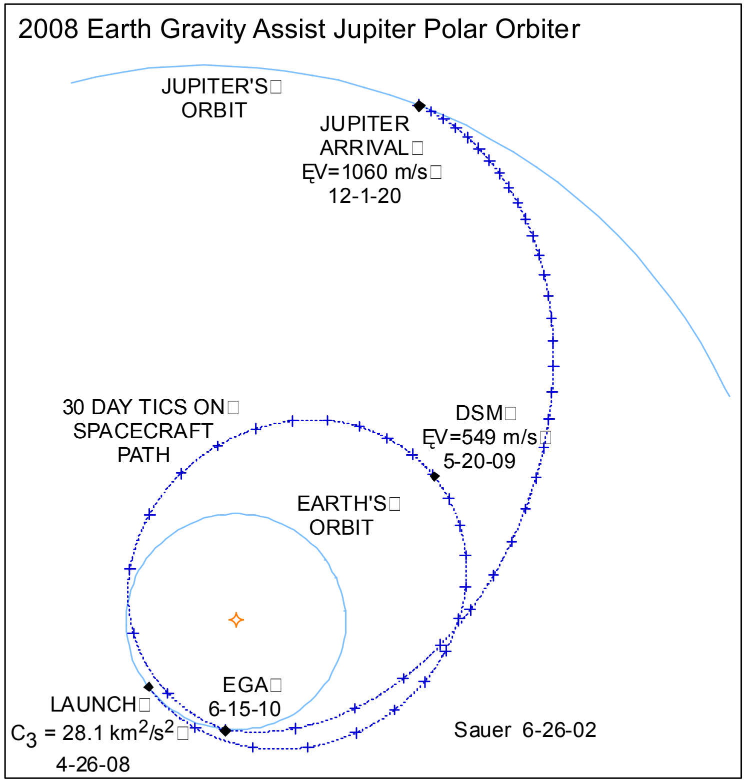
Coverage

- All latitudes and local times
- Weekly sampling periods

Minimum Technology Design was Baselined

- No "enabling" technology required
- New enhancing technology should reduce spacecraft cost by 10%

Jupiter Polar Orbiter



Enabling Technology Development

- Radiation Hard Components
- Adaptive Feed/Uplink Beacon
- Internal 2-axis Slow Scanning Mirror IMC
- TDI Image Synthesis and Relative Motion Cancellation
- Synchronized Shutter for Imager Radiation Shielding
- Ka-band Transponder/TWTA/Switches

Science Objectives

- The Relative Contributions of Planetary Rotation and of the Interaction with the Interplanetary Medium to Jovian Magnetospheric Dynamics
- How Global Electric and Magnetic Fields Regulate the Processes that Produce the Radiation Belts, Plasma Sheet, and the Aurora
- Identify the Particles Responsible for the Generation of the Jovian Aurora and Determine their Magnetospheric Source Regions

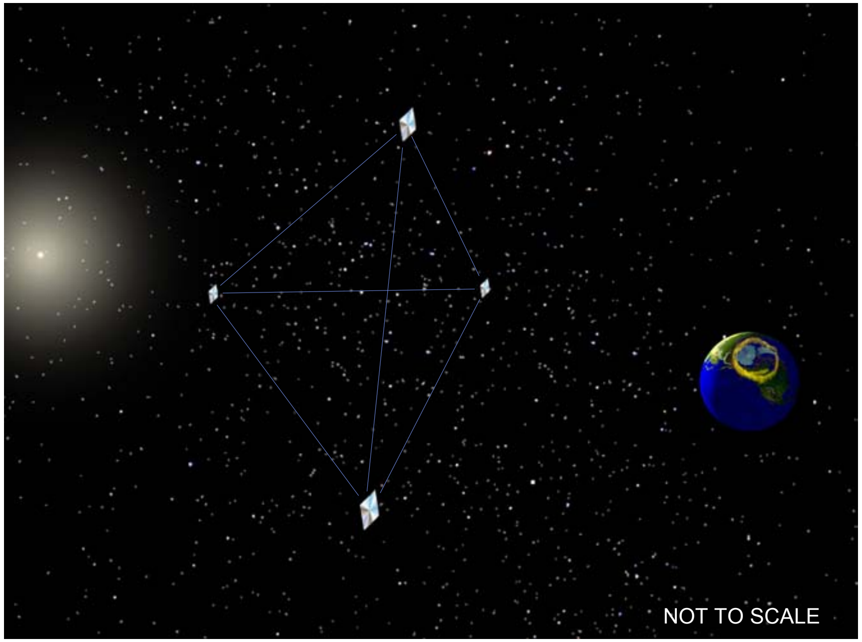
Mission Description

- Example Mission Design
  - Delta III/Star 48 Launch , 1658 kg @ $C_3 = 31\ km^2/s^2$ (28.1 min)
  - Elliptical Polar Orbit
    - 1.1 R_j x 40 R_j, 75° inclination
    - 4.6 Year cruise, 1-Year OPS
- Flight System Concept
  - Rad-Hard Spin-Stabilized Platform
  - Solar Array Implementation
  - Payload: Field & Particles, Imagery, Radio Science
    - 55 kg, 38 W, 4 kbps
  - 1758 m/s ΔV
  - Capability Driven Design
    - 900 arcsec (control), 36 arcsec (knowledge)

Measurement Strategy

- Measure Particles and Fields In-Situ in the Auroral Acceleration Region, Along L Shells, and in Conjugate Magnetospheric Source Regions
- Radio occultations of ionosphere and upper atmosphere
- Image Aurora in the Visible and UV
- Measure the Magnitude and Configuration of the Near-Planet Magnetic Field and Map the 3-D Structure of the Radiation Belts

L1-Diamond



Science Objectives

- Measure the properties of solar-wind turbulence (as seen in density, velocity vector and magnetic field) as a function of separation in space and time, ranging from the dissipation scales of perhaps hundreds of kilometers to the outer scale of millions-of-kilometers
- Direct measurements of the possible spatial symmetries of the turbulence
- Discover associations of the turbulence with suprathermal and energetic particles
- Measure the spatial variation in convected and propagating waves, shocks and other disturbances in the solar wind

Mission Description

- Example Mission Design
- Delta IV Launch Vehicle
  - Trajectory: ballistic transfer from Earth to L1 Halo (~90 days), solar sail transition from L1 to constellation stations,
    - 3 s/c in triangle formation, centroid 280 - 500 Re sunward of Earth on Sun-Earth line, 4th s/c above the ecliptic
    - Variable constellation baseline (for 3-D structure)
  - Continuous Solar Viewing: 3 years In Final Orbit
- Flight System Concept
  - 4 solar-array powered S/C with solar sails
  - Payload: Fields and Particles (~ 15 kg/9W)

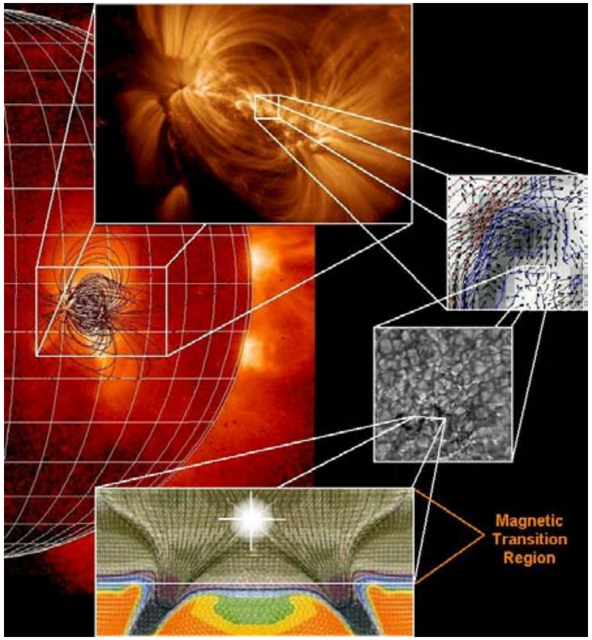
Measurement Strategy

- 4-s/c constellation with varying separations to study the full range of turbulence structures in both space and time
- High time resolution with time delays providing valuable correlations between the observed quantities

Enabling Technology Development

- Solar Sail
- Solar Sail Navigation Tools
- Autonomous Thrust Vector Control
- “Multi-Chip Module” (MCM) Electronics

Magnetic Transition Region Probe



Enabling Technology Development

- Large, light weight, reflecting optics for use in visible near IR and vacuum ultraviolet
- Extendable optical bench
- Large format (up to 16K x 16K pixels), low power, high QE at 150 nm, multiport CCDs.
- Image motion compensation/stabilization for large apertures and EUV
- Variable Emissivity Surfaces
- High Data Volume Ground Processing
- Instrument Auto-Boresighting System
- High Stability Platform
- Compact PCI Cards
- Ka-band Transponder/TWTA/Switches

Science Objectives

- Discover, measure, and understand the 3D structure and dynamics of the magnetic transition region between the photosphere and upper chromosphere.
- Connect the structure and events in the magnetic transition region with their photospheric roots and the magnetic stressing and heating of the chromosphere and corona.
- Resolve and measure the appearance, transport, and destruction of magnetic field on the fundamental intergranular scales in the photosphere.

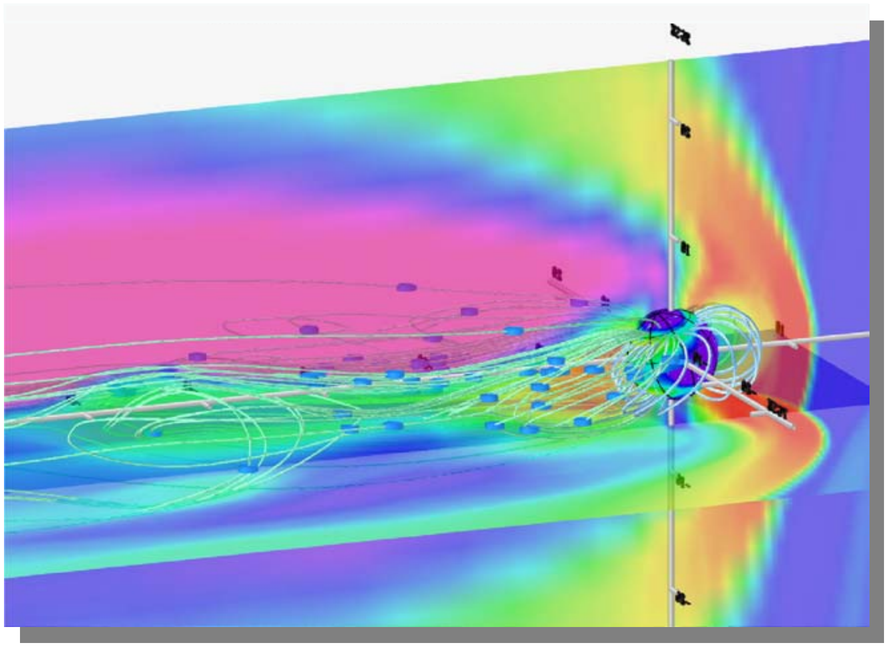
Mission Description

- Example Mission Design
  - Delta IV Launch Vehicle (due to shroud requirement)
  - Geo-synchronous, Earth-orbiting satellite
    - 3 years In Orbit
- Flight System Concept
  - 3-Axis Stabilized Solar Inertial Observatory Platform
  - Solar Arrays
  - 751 Mbps link to Ground Terminal
  - Payload: 570 kg, 330 W (peak), 750 Mbps
  - 36-as control (payload implements 10-as with 1-as knowledge)

Measurement Strategy

- Visible/infrared maps/images of vector magnetic field, intensity, and velocity in the magnetic transition region and the photosphere, with large FOV (> 100,000 km), high resolution (< 100 km), and high sensitivity (< 30 G, transverse).
- UV maps/images of line-of-sight magnetic field, intensity, and velocity in upper chromosphere/lower transition region.
- EUV images and spectra of coronal structures in and around the FOV of the magnetic transition region observations and with comparable resolution.

Magnetospheric Constellation (MC) Mission



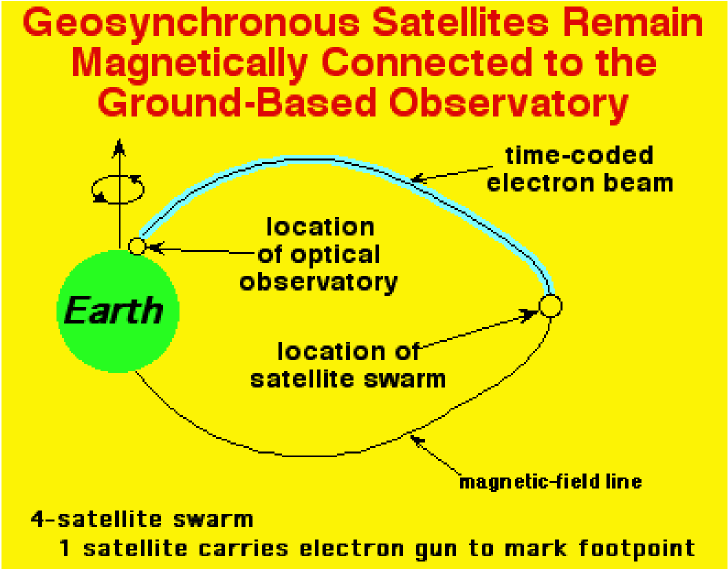
Science Objectives
- Define and characterize the magnetotail's responses to external and internal drivers
- Resolve space/time ambiguities that conceal the governing physical processes.

Mission Description
- A constellation of 50-100 nano-satellites distributed in 3x7 Re to 3x40 Re low inclination, nested orbits
- "Nearest neighbor" spacing peaks at 1.0-2.0 R_e for ~ 50 - 100 nano-sats

Measurement Strategy
- Systematic multi-point measurements of magnetic field, bulk plasma & energetic particle parameters
- Spacecraft deployed with optimal spatial distribution
- Prime mission conducted while in magnetotail; secondary science on flanks and dayside.

Key Mission Enhancing Technologies
- Cost effective fabrication, assembly and testing techniques for 50-100 nano-satellites
- Miniaturized, rad-tolerant, low mass/power instrumentation and support systems for an integrated "sciencecraft"
- Advanced data synthesis and visualization techniques

Magnetosphere-Ionosphere Observatory



Science Objectives

- Determine what causes the aurora
- Determine how 10's-100's of gigawatts of energy are extracted from the magnetotail
- Probe magnetosphere-ionosphere coupling

Mission Description

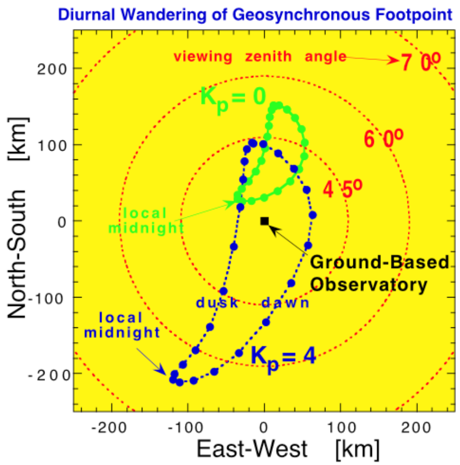
- Main spacecraft contains a high-power electron gun
- 3 satellite spacecraft in close cluster with main spacecraft
- Geosynchronous satellites remain magnetically connected full-time to ionospheric observatory
- All spacecraft carry critical measurement instruments
- Observatory locates the beamspot within the auroral ionosphere

Measurement Strategy

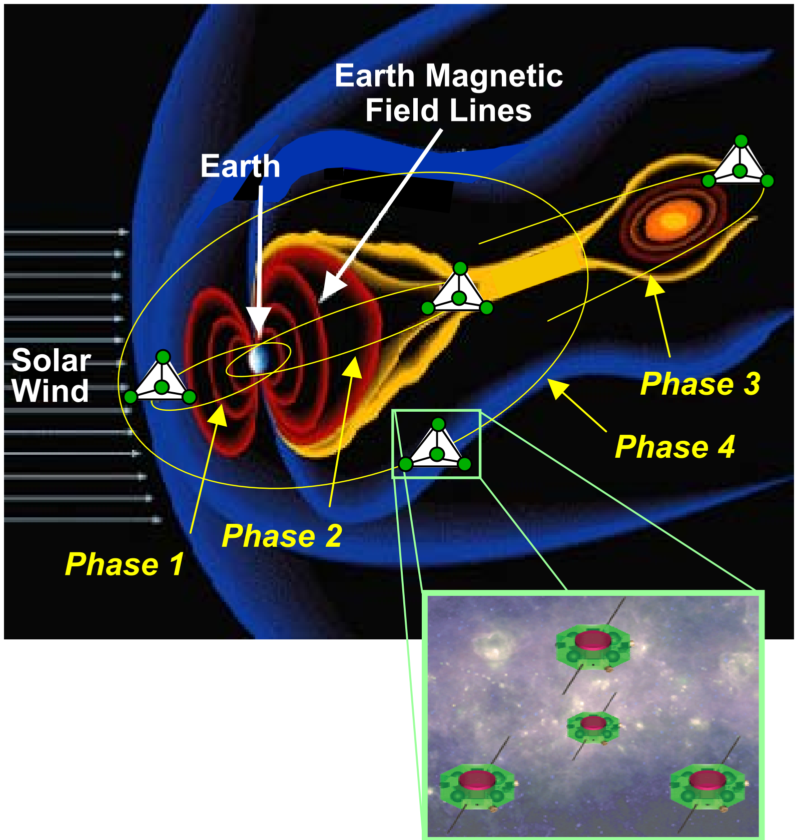
- Find the magnetospheric end of auroral arcs
- Verify position from electron-beam connection
- Measure plasma, flow, and field gradients in aurora using multiple spacecraft
- Discriminate among auroral arc theories

Minimum Technology Design was Baselined

- Exploits technologies developed by NASA's program in active space experiments.
- New enhancing technology should reduce spacecraft cost by 10%



Magnetospheric Multiscale (MMS)



Science Objectives

- Understand the fundamental plasma physics processes of reconnection, particle acceleration, and turbulence on the microscale and mesoscale in the Earth's magnetosphere.

Mission Description

- 4 spin-stabilized spacecraft in a tetrahedron constellation (2 year mission)
- Inter-spacecraft ranging system
- 4 orbital phases:
  - Phase 1: 1.2 R_E by 12 R_E, 10° incl. (9 months)
  - Phase 2: 1.2 R_E by 30 R_E, 10° incl. (3 months)
  - Phase 3: 8 R_E by 100-120 R_E lunar assist maneuver to achieve ~90° orbit plane change
  - Phase 4: 10 R_E by 40 R_E, 90° incl. (11 months)

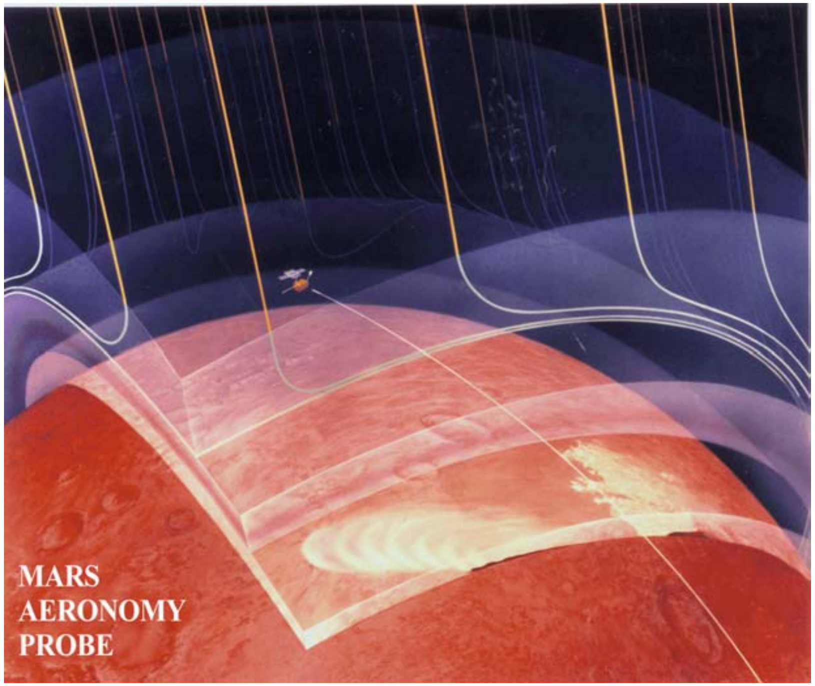
Measurement Strategy and Coverage

- 4 suites of identical instruments: electric field, energetic particles, hot plasma & magnetometer
- Measurements taken during 4 phases include:
  - Phase 1: Dayside Magnetopause: reconnection acceleration, turbulence, solar wind entry
  - Phase 2: Nightside Substorm: reconnection, plasma sheet boundry, accel., current disruption
  - Phase 3: Magnetotail: reconnection structures and dynamics, plasma escape/motion across boundary
  - Phase 4: Post-Cusp Magnetopause: northward re-connection, reverse convection, pointing flux entry

Minimum Technology Design was Baselined

- No "enabling" technology is required

Mars Aeronomy Probe



Technology Development

- Low Mass/Power Instrumentation
- Micro-Spacecraft Components and S/S

Science Objectives

- Map the Upper Atmospheric Composition, Thermal Profile and Global Circulation
- Determine the Properties of the Ionosphere, its Sources and Sinks, Dynamical Coupling to the Neutral Atmosphere Including Dust Storms and Gravity Waves and its Electrodynamic Response to the Solar Wind
- Observe the Response of the Upper Atmosphere to Solar Variability and Model the affects of Space Weather on Satellite Drag and Aerocapture
- Explores the processes for atmospheric escape

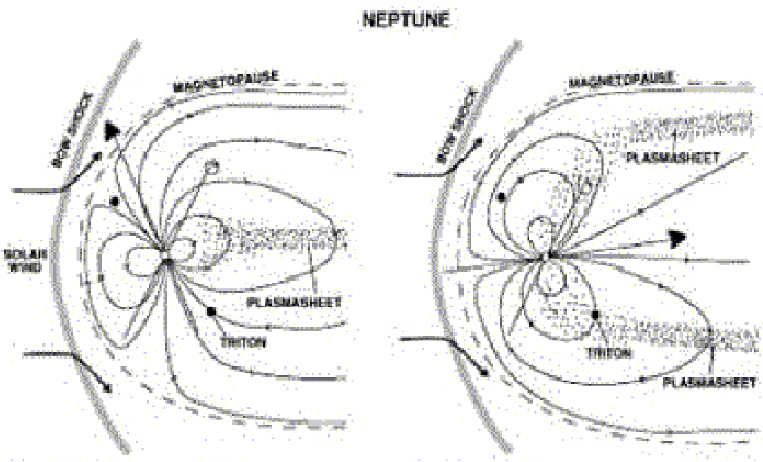
Mission Description

- Example Mission Design
  - Small Delta II
  - Elliptical Low-Altitude Polar Orbit
    - 100 km x 500 km
    - 1-year Flight Time, 2-year OPS
- Flight System Concept
  - Spin-Stabilized Platform
  - Solar Array Implementation

Measurement Strategy

- Neutral Species Escape Rates, Isotopic Ratios, Densities, Temperatures, Winds and Composition
- Thermal Plasmas (Ions and Electrons), Pick-up Ions, Energetic Particles and Magnetic and Electric Fields
- Integrated Theory and Data Analysis Program
- EUV/FUV spectra for remote sensing of escaping atoms

Neptune Orbiter



Enabling Technology Development

- Aerocapture (0.3 to 0.4 mass ratio)
- Advanced Telecom: Optical or large-diameter inflatable antenna
- Advanced Radioisotope Power
- Autonomous spacecraft operations

Science Objectives

- Map Neptune's highly asymmetric magnetic field
- Determine the magnetospheric structure as the highly oblique and offset magnetic field rotates with the planet
- Determine the densities, compositions, and temperatures of magnetospheric plasma populations, and their distributions throughout the magnetosphere
- Measure the plasma flows associated with the dynamics of the magnetosphere driven by the planet's rotation and by the solar wind
- Determine whether Triton has an intrinsic magnetic field, and characterize the plasma interaction with Triton and its atmosphere
- Compare the magnetosphere of Neptune with other planetary magnetospheres and compare the Triton-magnetosphere Interaction with the Galilean satellites of Jupiter and with the role of Titan in Saturn's magnetosphere

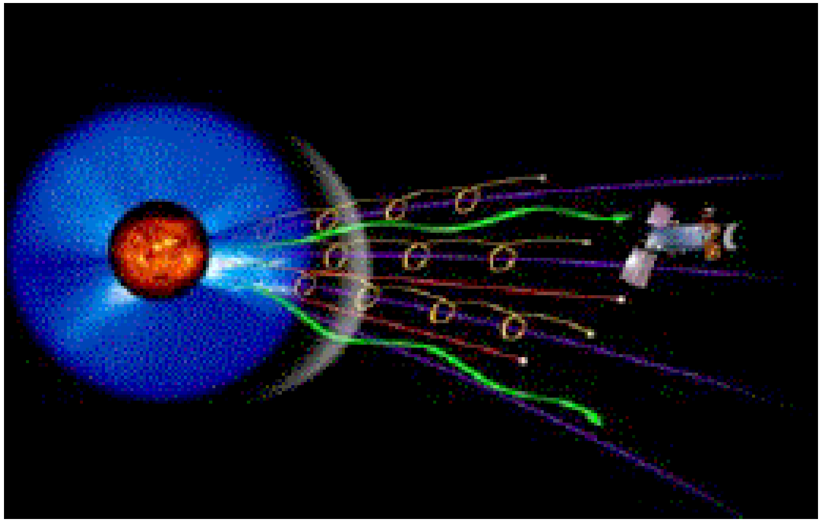
Mission Description

- Example Mission Design
  - Delta/Altas Launch (Jupiter Gravity Assist Trajectory)
  - 9-12 yrs to Neptune + 2 yrs in orbit
  - Aerocapture, Optical Com, μ-S/C Technology
  - Autonomous operation and navigation
  - Multiple flybys of Triton
- Flight System Concept
  - Fields & Particles Instrumentation (Plasma, Energetic Particle, Magnetic & Electric Fields)

Measurement Strategy

- Thermal plasmas, energetic particles, magnetic and electric fields, plasma waves, and auroral measurements (including UV spectral imaging of Neptune and Triton)
- Integrated theory and data analysis program involving numerical simulations processes, and energetic-particle acceleration under a variety of planetary magnetic-dipole orientations

Particle Acceleration Solar Orbiter



Science Objectives

- Understand particle acceleration mechanisms
- Distinguish between flare and shock accelerated particles
- Study location and nature of energy release and particle acceleration for the most energetic particles.
- Determine conditions for shock acceleration and evidence for post-eruption magnetic reconnection.
- Study active region evolution

Mission Description

- Example Mission Design
  - Delta II Launch ($C_3 = 0$ km^2/s^2)
  - Solar Sail Trajectory
    - Transfer From 1 AU to a 0.169 AU Circular Solar Equatorial Orbit (Period: 25.4 days)
    - 3-Year Transition to Final Orbit
  - Continuous Viewing of Active/CME Source Region
    - 4-5 years In Final Orbit
- Flight System Concept
  - Spin-Stabilized Platform (500 kg [inc. 80 kg of Sci.])
  - Advanced Thermal Design for 0.16 AU Orbit

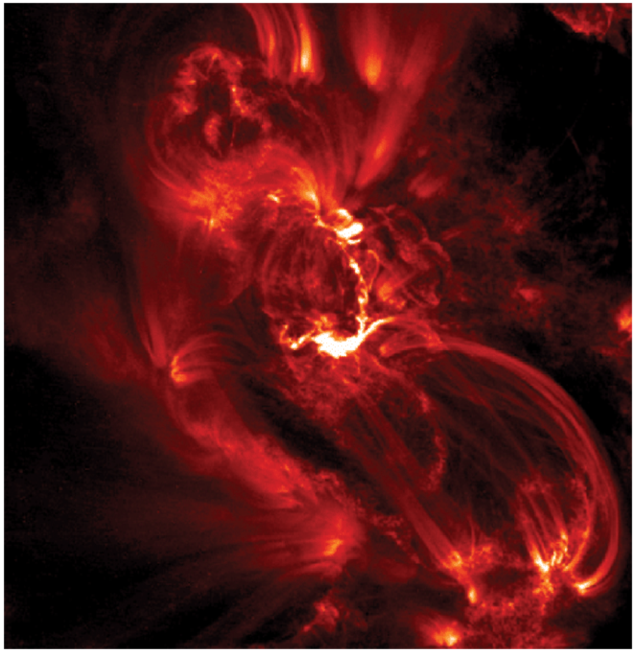
Measurement Strategy

- High energy solar flare imager (< 1 arcsec)
- 1-100 Mev/nuc, resolve composition up to Fe
- Neutron spectrometer, > 5MeV neutrons
- Gamma-ray spectrometer for nuclear lines
- Solar Wind and magnetic field instruments

Enabling Technology Development

- Solar Sail @ 9 g/m^2, 87 m Radius
- High Temperature Solar Arrays
- Solar Sail Navigation Tools
- Autonomous Thrust Vector Control
- Advanced Thermal Control

Reconnection And Microscale (RAM)



Minimum Technology Design was Baselined

- Enabling technology required - Large array, small pixel calorimeters for soft x-ray spectroscopy
- New enhancing technology should reduce spacecraft cost by 10%

Science Objectives

- What are the mechanisms that lead to reconnection?
- What micro-scale instabilities lead to global effects?
- Where are the regions of particle acceleration?
- Where are the reconnection regions and what is their topology?

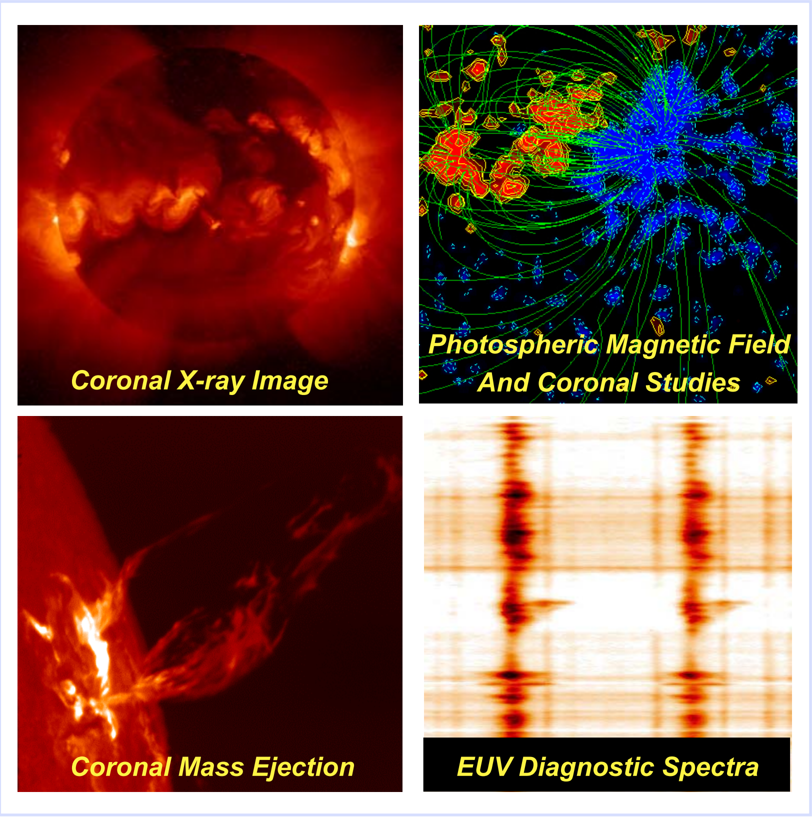
Mission Description

- Mission Design
  - Solar observations from single geosynchronous platform
  - Mission lifetime of 2 years
- Payload
  - High Resolution EUV Imaging instrument
  - EUV spectrograph
  - X-ray calorimeter
  - EUV Intermediate Scale Imager

Measurement Strategy

- Ultra-high resolution (0.02"/pixel) EUV coronal imaging
- High resolution (0.1"/pixel) EUV/UV spectroscopy
- X-ray Imaging Spectroscopy (1"/pixel; (E/DE) ~ 500 @ 1 keV) from 0.2 to 10 keV, with millisecond time resolution.
- Multi-wavelength EUV/UV intermediate scale imager (0.1"/pixel)
- High time resolution in all instruments

Solar-B



No “enabling” technology required.

Science Objectives

- To follow the flow of magnetic energy from the Sun’s photosphere to the corona in order to understand the steady state release of energy, which heats the corona and the transient release of energy that produces CMEs and solar flares.

Mission Description

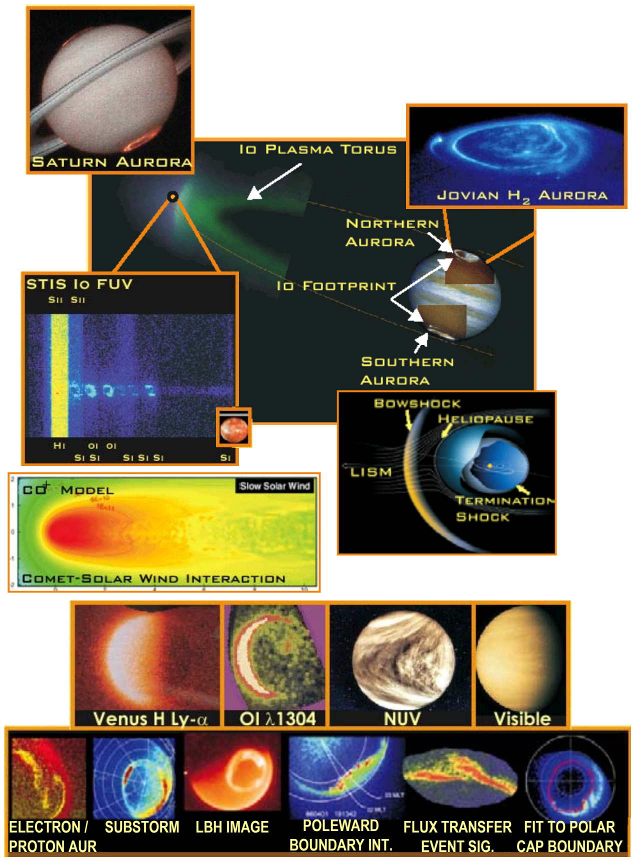
- Japanese mission with international partners.
- Single satellite in a Sun-synchronous, 600 km circular orbit, for continuous 24 hr coverage.
- Minimum mission lifetime 3 years with 8-year lifetime desirable.
- Three remote sensing telescopes observe the Sun in the optical (SOT/FPP), ultraviolet (EIS), and X-ray (XRT).
- Image motion compensation enables 0.25 arcsec angular resolution in the visible.

Measurement Strategy

- The three telescopes have overlapping fields of view and can observe the same features simultaneously.
- The FPP will measure photospheric vector magnetic fields and granulation dynamics.
- The XRT will measure the coronal response to changes in the photospheric magnetic field and provide coronal temperature and density diagnostics.
- EIS, an imaging spectrometer, will provide spatially resolved temperatures, densities, and velocities of the material in the chromosphere and corona.

Solar Connections Observatory for Planetary Environments

SCOPE



Technology Requirements

- Light-weight, metal-matrix-composite mirror design
- High- sensitivity/dynamic-range photon counting UV detectors

Science Objectives

- Compare the global effects of external and internal driving mechanisms on planet and comet near-space environments through observations of auroral, airglow, coronal, and/or internal plasma emissions
- Differentiate features of Jupiter's (and other giant planets') auroral emissions due to internal processes (rotation and internal plasma sources) from those due to the solar wind interaction
- Measure the response of ionosphere-solar wind coupling to changes in solar activity in planet systems without magnetospheres (Mars, Venus, Comets)
- Refine and expand our knowledge of Earth's global geospace response by extending auroral observations into new domains of spatial and spectral resolution
- Directly compare the terrestrial solar interaction with those of superior (Mars-Neptune) planets from opposition campaigns that monitor both systems along the same Sun-planet line
- Map the opacity and velocity structure of the interplanetary hydrogen
- Study the transition region between the heliosphere and LISM

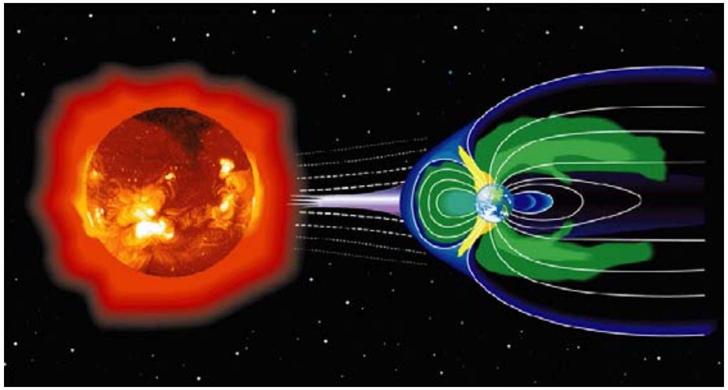
Mission Description

- Dual meter-class telescopes (EUV & UV) covering bandpasses from 55 - 310 nm
- Hubble Space Telescope (HST) - class performance for UV observations. Highest sensitivity and spatial resolution yet achieved below 120 nm
- High ($R<10^5$) spectral resolution measurements of diffuse emissions with 50 times the etendue of HST-STIS.
- Inner solar system observations of Venus, Mercury, and comets to within ~0.35 AU of the Sun
- L1-halo orbit for uninterrupted observations of the Earth's North or South polar regions and a remote perspective on planets giving full hemisphere studies up to rotational poles.
- 5+ years potential operational lifetime

Measurement Strategies

- Global imaging of auroral emissions, upper atmospheric circulation, exospheres and near-space plasma distributions
- Imaging spectroscopy of UV ion-neutral emissions and atmospheric absorption features
- Narrow-field spectroscopy of planetary (auroral-dayglow-coronal) H Ly-α profiles
- Wide-field line profile measurements of diffuse H Ly-α emission from the interplanetary medium (IPM), comets, geocorona,and the heliopause
- Pencil-beam measurement of heliopause and LISM dynamics from H Ly-α and H Ly-β line-of-sight absorption spectroscopy
- High speed photon counting detectors for precision time resolution
- Coordinated SCOPE observations of planetary targets, the IPM and heliopause with existing in situ space probes
- Cross-cutting techniques for characterizing auroral emissions in planetary magnetospheres, such as the development of auroral indices as a function of precipitating species at each of the planets (i.e., hemispheric power, auroral oval location, auroral oval size, etc.)

Solar Dynamics Observatory (SDO)



Science Objectives

- Understand the nature and source of the solar variability that affects life and society
- Make accurate measurements of the solar parameters that are necessary to provide a deeper understanding of the mechanisms that underlie the Sun's variability on timescales ranging from seconds to centuries
- Through remote sensing, monitor and record those aspects of the Sun's variable radiative, particulate, and magnetic plasma outputs that have the greatest impact on the terrestrial environment and the surrounding heliosphere.

Mission Description

- NASA GSFC will manage the mission, build the S/C in-house, manage & integrate the instruments, develop/manage the Ground System & Mission Operations, & perform Observatory environmental testing at GSFC
- August 2007 Delta launch from KSC into GEO-Transfer Orbit (GTO), circularize to GEO-Sync Orbit, inclined 28.5 degrees
- Investigations responsible for development of their Instrument & Science Operations Center. SDO Investigations will be selected 09/02

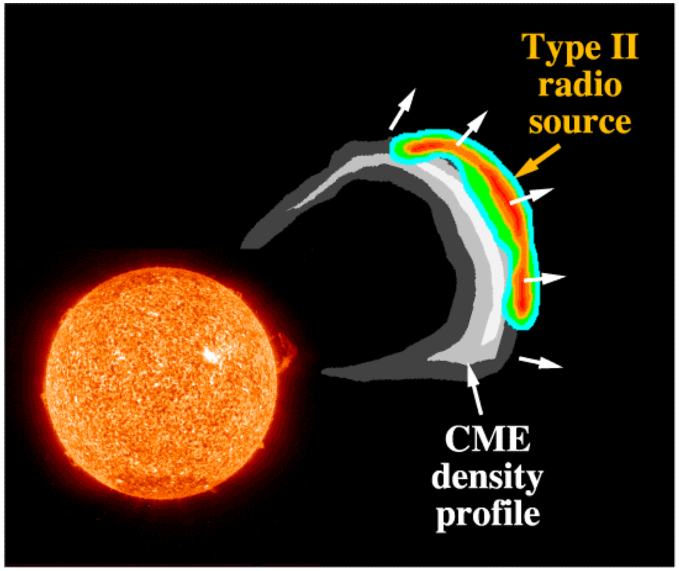
Enabling Technology Development

- C&DH Ethernet
- Ka-Band Telecommunications
- Active Pixel Star Tracker
- Radiation Hardened Field Programmable Gate Array (RHrFPGA)

Measurement Strategy

- <u>Helio/Magnetic Imager</u>: near- Diagnostic measurements of the near-surface dynamics of the solar interior
- <u>Atmospheric Imaging Assembly</u>: Characterization of the rapid evolution of the plasma in chromosphere and lower corona
- <u>Spectrometer for Irradiance in the Extreme-Ultraviolet</u>: Full disk observations of Solar EUV with 0.1 nm resolution
- <u>White-Light Coronagraphic Imager</u>: measure polarized intensity in white light to detect/characterize Coronal Mass Ejections (CME's)

Solar Imaging Radio Array



Two dimensional radio imaging of the CME-driven shock front and the CME density profile is critical for predicting the space weather effects of CMEs

Technology Requirements

- Intermicrosat ranging (to ~3 m)
- "Full-sky" aperture synthesis mapping algorithm development
- Onboard data cross-correlation desirable (for space weather snapshots)

Science Objectives

- Understand CME structure, propagation, and evolution from the Sun to 1 AU
- Apply solar radio burst images to mapping of solar wind density structures and magnetic field topology, providing a unique tool for solar wind analysis
- Enhance space weather prediction capabilities using radio images of CMEs
- Observe and analyze the global response of Earth's magnetosphere to CMEs and other space-weather-effective events from an external perspective
- Image the low-frequency (< 30 MHz) radio universe at high angular resolution and catalog and understand the objects found therein

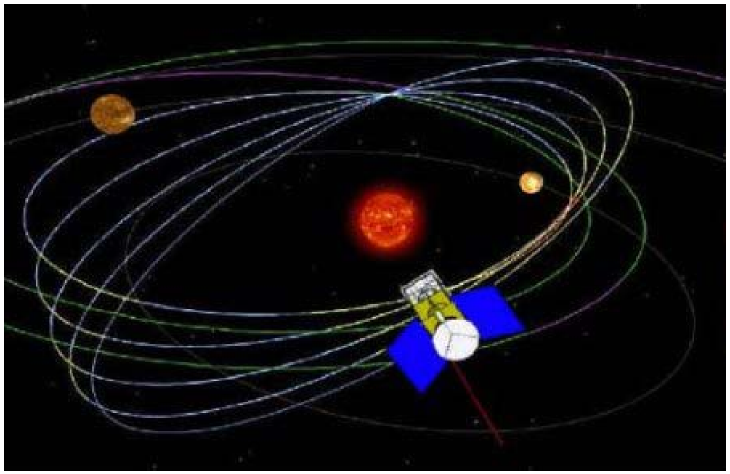
Mission Description

- Microsat constellation of 10 – 16 identical spacecraft
- Crossed dipole antennas and low frequency radio receivers
- Quasi-spherical constellation with <100 km diameter
- Nearly circular distant retrograde orbit (~10^6 km from Earth) or other terrestrial radio interference limiting orbit
- Individual microsat communication with ground stations

Measurement Strategies

- High spatial and temporal resolution
- Frequency range from ~30 MHz to ~30 kHz
- Frequency spacing and time resolution optimized for solar burst analysis
- Rapid data processing for space weather prediction

Solar Orbiter



Technology

- Solar Electric Propulsion to be validated on ESA SMART-1 mission in 2003
- High temperature thermal management to accommodate solar intensity 25x than seen at Earth

Science Objectives

Key science questions to be addressed are:

- What are the fundamental physical processes at work in the solar atmosphere and in the heliosphere?
- What are the links between the magnetic-field-dominated regime in the solar corona and the particle-dominated regime in the heliosphere?
- How does the Sun rule interplanetary space?
- What are the properties of plasma, fields and particles in the near-Sun heliosphere?
- What is the fine-scale structure and dynamics of the Sun’s magnetized atmosphere?
- What is the structure and dynamics of the Sun’s polar regions?

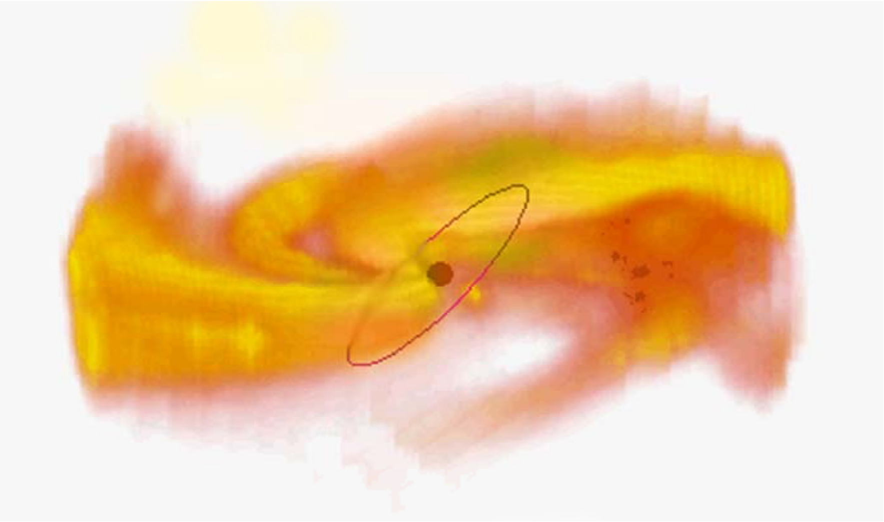
Mission Description

- ESA Mission
- 3 axis stabilized spacecraft will use solar electric propulsion and multiple planetary swing-by manoeuvres to reach a perihelion of 45 solar radii (0.2 AU) at an orbital period of 149 days.
- Multiple VGAs to increase inclination of orbital plane 30 degrees
- Perihelion “Hover” period during perihelion passes will allow imaging of solar storm buildup over several days.

Measurement Strategy

- Two instrument suites: in-situ + remote sensing
- Heliospheric in-situ: solar wind plasma analyser, radio and plasma wave analyser, magnetometer, energetic particle detectors, interplanetary dust and neutral particle detectors, neutron detector.
- Remote sensing: high resolution EUV imager and spectrometer, visible-light telescope and magnetograph, coronagraph, radiometer.
- Co-rotation during perihelion passes ⇒ steady magnetic linkage ⇒high resolution imaging + spectroscopy of solar atmosphere coupled with in-situ plasma measurements
- Out-of-ecliptic observations: magnetic fields, rotation and subsurface flows near poles, longitudinal extent of CMEs, global corona

Solar Polar Imager



Science Objectives

- Measure near-surface meridional circulation
- Measure sub-surface jets and azimuthal and meridional circulation
- Measure the Sun's polar magnetic field and refine solar dynamo models
- Measure global oscillations on the far side of the Sun
- Image global effects of CMEs and evolution on the full 3-D corona
- Track the complete life cycle of active regions and coronal holes
- Link variations in the high-latitude heliosphere to surface conditions
- Measure angular momentum loss in the solar wind

Mission Description

- Example Mission Design
  - Launch: Delta II 2425, 769 kg @ $C_3 = 0.25\ km^2/s^2$
  - Solar Sail Trajectory
    - 4 - 5 Year Flight Time, 2 year OPS
  - Final Orbit: 0.48 AU Circular Solar Orbit with 60° Inclination
    - 3:1 Resonance with Earth
- Flight System Concept
  - 3-Axis Stabilized
  - Solar Array Implementation
  - Payload: 34 kg, 24.5 W, 15.6 kbps

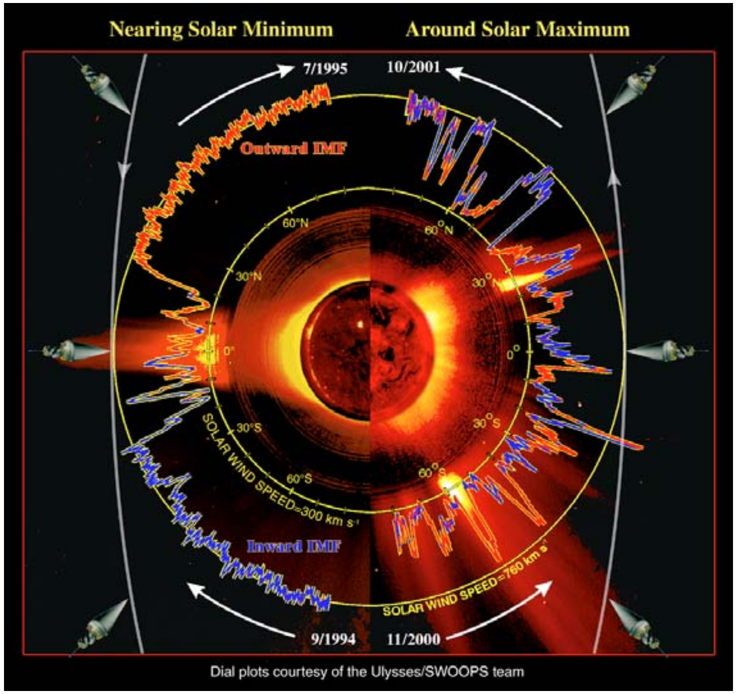
Measurement Strategy

- Surface Velocity for Helioseismology Investigations
- High Latitude Magnetic Fields and Coronal Holes
- Image Corona and Inner Heliosphere from Over Poles
- Image Coronal Mass Ejections in the Ecliptic Plane
- In-situ Particles and Fields Measurements
- Solar Irradiance in Polar Regions

Enabling Technology Development

- Solar Sail @ 10-14 g/m^2, $\sqrt{A}$ = 100-141 m
- Micro-S/C Components and Subsystems
- Low Mass/Power Instrumentation
- Autonomous Thrust Vector Control
- Solar Sail Navigation Tools

Solar Probe



Dial plots courtesy of the Ulysses/SWOOPS team

Science Objectives

- Determine the acceleration processes and find the source regions of fast and slow solar wind at minimum and maximum solar activity
- Locate the source and trace the flow of energy that heats the corona
- Construct the 3-D coronal density configuration from pole to pole; determine the subsurface flow pattern and the structure of the polar magnetic field and its relationship with the overlying corona
- Identify the acceleration mechanisms and locate the source regions of energetic particles, and determine the role of plasma waves and turbulence in the production of solar wind and energetic particles

Mission Description

- Mission Design
  - Launch opportunity every 13 months (baseline is May 2010 launch)
  - Two solar passes (polar, 4 R_S) within 7.1 yr; three within 11.1 yr
  - Atlas 551/Star-48B launch vehicle; 713 kg @ C_3 = 128 km^2/s^2
  - JGA trajectory with post-perihelion ΔV for successive passes
  - 3.1-yr cruise; 0.02 × 5 AU final orbit with period of 4 yr
- Flight System Concept
  - 15° half-angle conical carbon-carbon heat shield
  - 3-axis stabilized with 0.2° pointing control and 0.05° knowledge
  - RTG power source (3 Multi-Mission RTGs supply 330 W BOL)
  - Ka-band downlink, X-band uplink using 34-m DSN dishes
  - Data rate: up to 40 kbps real-time with 200 kbps additional stored data
  - Payload: 50 kg, 47 W

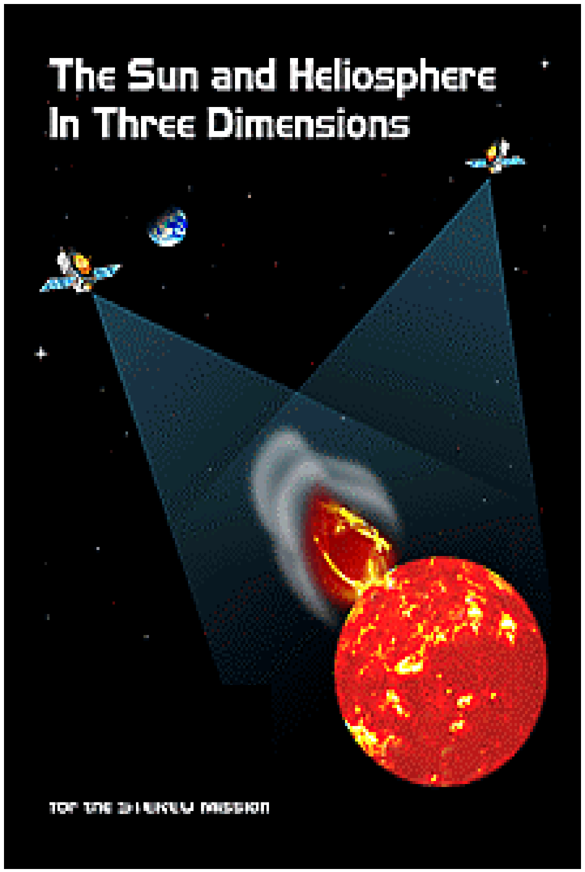
Enabling Technology Development

- Thermal Protection System for 3000 Sun Environment
- Ka-Band Telecommunications
- Multi-Mission RTGs

Measurement Strategy

- In situ instruments (solar wind electrons & ion composition, magnetometer, energetic particle composition, plasma waves, & fast solar wind ion detector)
- Remote-sensing instruments (EUV imager, visible magnetograph-helioseismograph, & all-sky 3-D coronagraph)
- Characterize the solar wind within a high-speed stream
- Characterize the plasma in a closed coronal structure and probe the sub-sonic solar wind
- Image the longitudinal structure of the white-light corona from the poles
- Produce high-resolution images in each available wavelength
- Characterize plasma waves, turbulence, and/or shocks that cause coronal heating
- Determine the differences in sw characteristics during solar max and min

Solar Terrestrial Relations Observatory (STEREO)



Technology Development

- No enabling technologies required.

Science Objectives

- Understand the causes and mechanisms of CME initiation
- Characterize the propagation of CMEs through the heliosphere
- Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium
- Develop a 3D time-dependent model of the magnetic topology, temperature, density, and velocity structure of the ambient solar wind

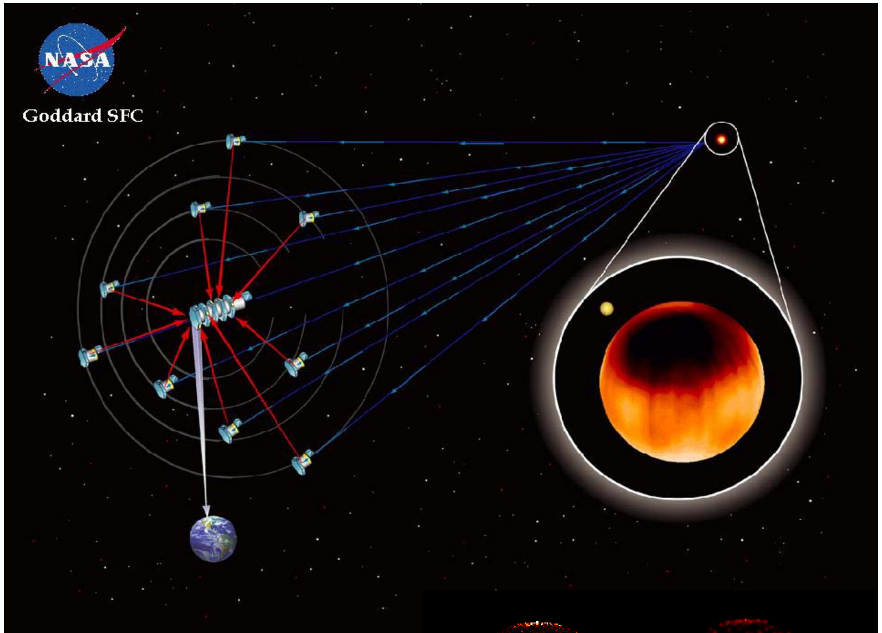
Mission Description

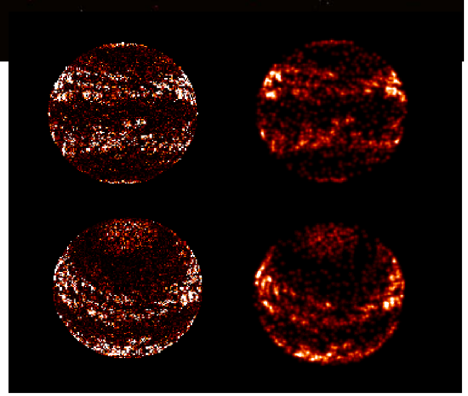
- Two Functionally Identical Spacecraft in Heliocentric Orbits at 1 AU (22°/yr Drift From Earth Orbit Leading/ Lagging Configuration).
- The 3 year STEREO mission is a multilateral international collaboration involving participants from France, Germany, the United States and the United Kingdom
- The investigations include a Sun-Earth Connection Coronal and Heliospheric Investigation (SECCHI), a STEREO/WAVES (SWAVES) interplanetary radio burst tracker, an In Situ Measurements of Particles and CME Transients (IMPACT), and a PLAsma and Suprathermal Ion and Composition experiment (PLASTIC).

Measurement Strategy

- SECCHI will track Coronal Mass Ejections (CMEs) from the Sun to the Earth utilizing
- Two White Light Coronagraphs, an Extreme Ultraviolet Imager, and a Heliospheric Imager with overlapping fields of view to observe the same features simultaneously
- IMPACT will sample the 3-D distribution of solar wind plasma electrons, the characteristics of the energetic particle ions and electrons, and the local magnetic field utilizing a Solar Wind Experiment, a Suprathermal Electron Telescope, a Magnetometer Experiment, and a Solar Energetic Particle Experiment Suite
- PLASTIC will provide the plasma characteristics of electrons (1-1000 eV) protons, alpha particles, and heavy ion (300-8000 eV) that characterize the CME plasma
- SWAVES utilizes in-situ as well as remote sensing mesurements to tracks CME Driven Shocks from the Corona to the Earth

Stellar Imager





Science Objectives

- Explore the patterns in surface magnetic fields throughout activity cycles on a substantial sample of stars like the Sun in order to develop and test a predictive dynamo model for the Sun.
- Image the evolving dynamo patterns on nearby stars by repeatedly observing them with ~1,000 resolution elements on their surface using UV emission as a proxy for magnetic field.
- Image the structure and differential rotation of stellar interiors by the asteroseismic technique of acoustic imaging, achieving 30 resolution elements on stellar disks with 1-min. time resolution in one or more broad optical pass bands.

Mission Description

- Days to weeks of uninterrupted observing from a very stable environment, such as L2
- Strategic mission, with 9 or more coordinated spacecraft
- Mission lifetime: 5-10 years

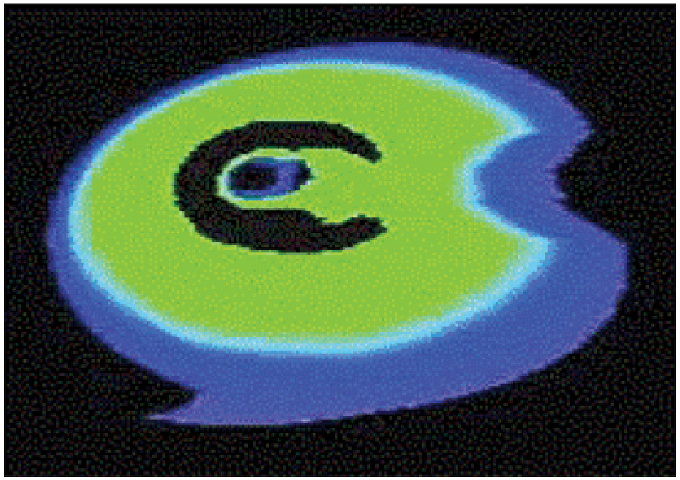
Measurement Strategy

- Angular resolution of images better than 0.1 milli-arcsec
- Reconfigure the imaging array fast enough to obtain images of stars within 1% of their rotation period
- Compile at least ~20 images within a stellar rotation period to measure surface differential rotation and field evolution
- Revisit targets repeatedly during 3-6 month intervals over a period of 5-10 years.
- Determine the interval structure and rotation with adequate resolution in layers where the dynamo operates

Key Technology Requirements

- Precise formation flying with low-mass, efficient propulsion
- Interferometric beam combining with ~5nm precision

Sun-Earth Energy Connector (SEEC)



Studying the plasmasphere is one aspect of tracing the flow of radiant EUV energy from the Sun to determine its effect on the Earth.

Technology Requirements

- Ionospheric 911Å imaging system
- Simultaneous Sun and Earth viewing at >3RE
- Optics-free photoelectron spectrometer

Science Objectives

- Quantify the relationships between solar radiation and space weather on local and planetary scales by:
  - Specifying solar EUV radiation variability and its source mechanisms
  - Simultaneously mapping the neutral and plasma near-Earth space environments
  - Establishing instantaneous relationships among solar radiation, precipitating energetic particles, and the space environment

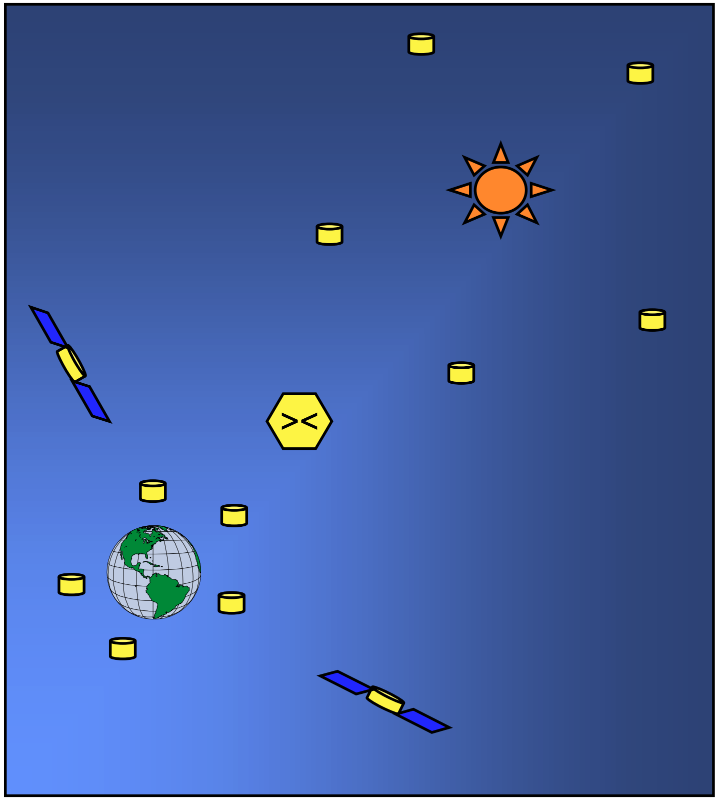
Mission Description

- MIDEX or STP class mission
- Orbit at >3RE, ~50° inclination
- Simultaneous imaging of the Sun's outer atmosphere and Earth's neutral atmosphere, day-night ionosphere, and plasmasphere

Measurement Strategies

- Simultaneous global images of the Sun and Earth
- High-angular-resolution images to observe local thermosphere, ionosphere, and plasmasphere weather
- Simultaneous high-accuracy solar EUV irradiance spectrum made with order-free spectrometer
- Development of new versions of neutral density and plasmaspheric-ionospheric models

Sun, Heliosphere, Earth Constellation



Science Objectives

- Provide long-term relevant information on the Earth, Sun and its interconnecting medium as a system
- Understand, monitor and track the Sun, Earth and Heliosphere as a dynamic and evolving system
- Provide timely reports and predictions on the status and possible major disturbances in the Earth, Sun System

Mission Description

- Establish an operational constellation of sensor suite(s) that satisfies the mission objectives
- Deploy sufficient sensors to measure the relevant data with adequate spatial and temporal and resolution
- Implement a data processing capability and information network to provide the required products and services
- Refresh, replace and enhance space borne constellation elements over time
- Improve modeling and algorithms as understanding and assets increase

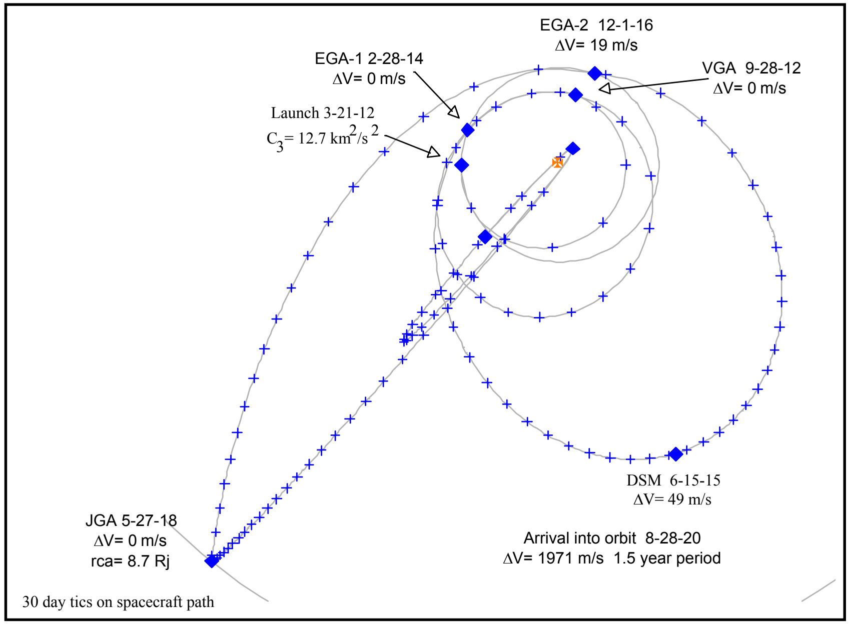
Technology Requirements

- Constellation suite(s) of sensors will all be developed and verified as roadmap missions are accomplished
- Technology to integrate multiple data streams from multiple sources to provide timely operational results may be needed

Measurement Strategy

- Remote sensing of the Sun from locations needed to provide data for proven predictive models
- In-situ sensors to measure key parameters in the Earth Sun interconnecting medium.
- Near Earth remote and in-situ measurements to complete and verify the monitoring and modeling of the Earth Sun System

Telemachus



Science Objectives

- Understanding our changing Sun and its effects throughout the Solar System (Space Science Enterprise Strategic Plan, November 2000)
- Reveal through helioseismology how convection and rotation coupleand magnetic flux accumulates in the polar regions (solar dynamo)
- Uncover the mechanism(s) in the polar regions of the Sun that accelerate the solar wind and energetic particles and expel plasma and magnetic fields (CMEs)
- Exploit the polar viewpoint to examine the distribution of radio and x-ray emission simultaneously from all solar longitudes
- Determine the physics of the strongest stream/stream plasma interactions and transient shocks where they are first formed in the heliosphere

Mission Description

- Example Mission Design
  - Delta III Launch, 1765 kg @ C_3 = 17 km^2/s^2 (12.7 min)
  - VEEJGA Trajectory with Perihelion ΔV
    - 8.4 yr cruise, 3 yr science ops
    - 0.2 x 2.5 AU Final Orbit, Period: 1.5 years
  - 90° Heliographic Inclination
    - 1st 4.5 years ecliptic (VEEJGA); 3 years In Final Orbit (polar)
- Flight System Concept
  - 3-Axis and Spin-Stabilized Platform
  - Solar Arrays (Ultraflex, High Efficiency Silicon, High Temp Cells)
  - Payload: 33 kg, 42 W, 8 kbps
  - 2239 m/s ΔV
  - 30 arcsec (control), 10 arcsec (knowledge)

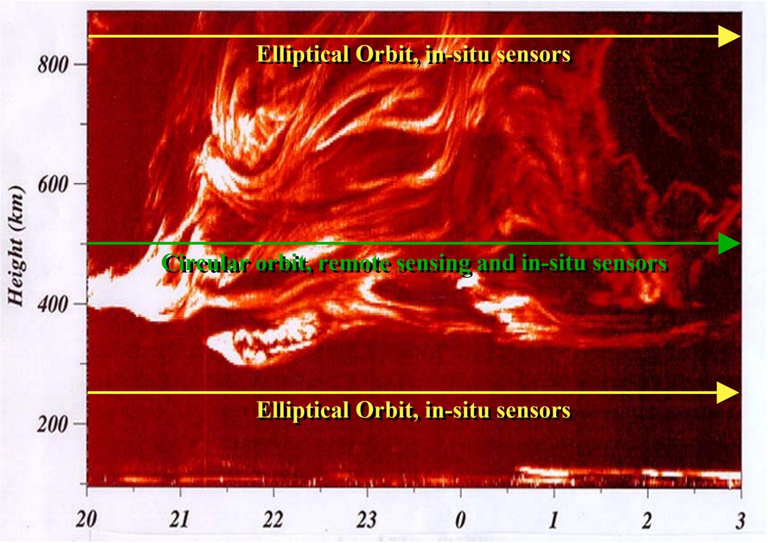
Enabling Technology Development

- High Temperature Solar Arrays
- Dual Mode ACS (high precision 3-axis and F&P spin mode)

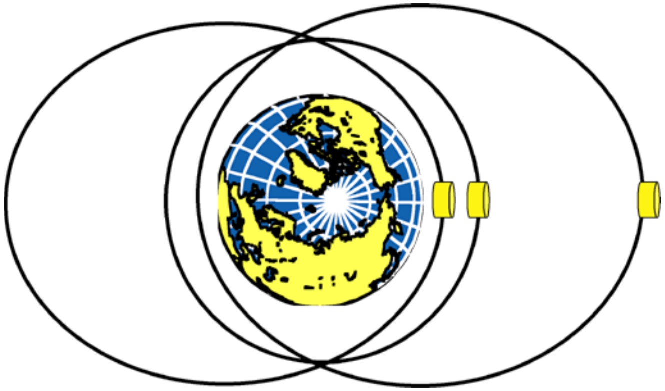
Measurement Strategy

- Continuous science except for 2 years beyond 3 AU (JGA)
- Optimized Solar and heliospheric imagers (Doppler magnetograph, two white light)
- Basic, proven fast plasma, magnetic field and energetic particles in situ detectors
- Improved plasma elemental and isotopic composition for coronal diagnostics and interstellar/cometary/"inner source" pickup ions
- Sensitive radio directional spectrograph and x-ray spectrometer

Tropical ITM Coupler



Local Time



Minimum Technology Design was Baselined

- No "enabling" technology required
- New enhancing technology should reduce spacecraft cost by 10%

Science Objectives

- Measurement of neutral and plasma electro- dynamics at different altitudes simultaneously.
- Determine the coupling between the Earth's low latitude mesosphere, thermosphere, ionosphere, and inner plasmasphere.

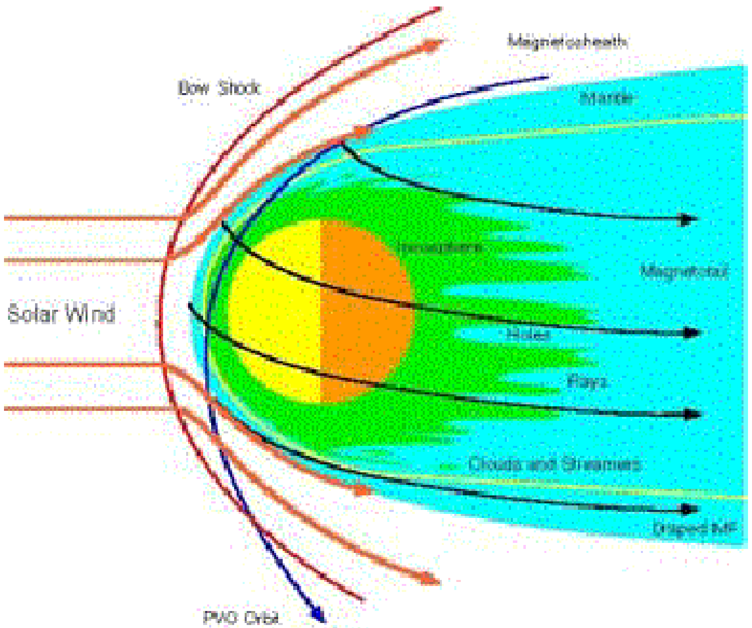
Mission Description

- 3 satellites with identical orbit periods and the same low inclination (<20°)
  - 2 with elliptical orbits (250 x 1500 km)
    - Apogees: 180 degrees apart
    - Dipping to 150 km perigee
  - 1 with a circular orbit of 600 km
- Payload (ram and nadir pointing)
  - 8 in-situ instruments on all 3
  - 4 remote sensing on circular spacecraft

Measurement Strategy

- Remote sensing: gravity waves, airglow, neutral winds, plasma density profiles;
- In-situ: electric, magnetic fields, thermal, energetic plasma, neutral properties, winds, lightning;
- Coverage (continuous in each orbit):
  - Conjunctions of the two elliptical satellites with each other and the circular satellite provide investigations of vertical coupling

Venus Aeronomy Probe



Science Objectives

- Determine Mechanisms for Energy Transfer From the Solar Wind to the Ionosphere and Upper Atmosphere
- Measure the Charged Particles Responsible for Auroral-Type Emissions and Infer their Acceleration Mechanisms
- Determine Formation Processes for Ionospheric Magnetic Flux Ropes, Ionospheric “Holes” on the Nightside and the Loss of Ionospheric Plasma in the Form of Streamers, Ray and Clouds

Mission Description

- Example Mission Design
  - Small Delta II
  - 1-Year Flight Time, 1year OPS
  - High Inclination Elliptical Orbit
    - 150 km x 12,000 km
- Flight System Concept
  - Spin-Stabilized Platform
  - Floating Potential Neutralization
  - Solar Array Implementation

Technology Development

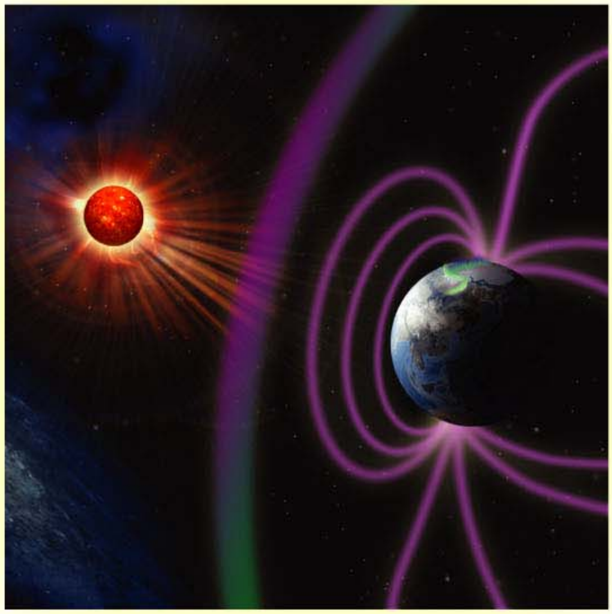
- Low Mass/Power Instrumentation
- Intelligent Instruments
- Non-Disruptive Floating Potential Neutralization

Measurement Strategy

- In-situ Plasma, Magnetic and Electric Fields and Plasma and Radio Wave Measurements
- In-situ Neutral Gas Composition, Density, Temperature, and Winds Measurements
- Remote Observations using a UV Spectral Imager, Fabry-Perot Interferometer, Energetic Neutral Atom Imager, Ionospheric Sounder

Sun-Earth Connection

ROADMAP 2003-2028



Understand the Sun,

Heliosphere, and Planetary

Environments as a Single

Connected System

http://sec.gsfc.nasa.gov

National Aeronautics and
Space Administration

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